ANGLIA RUSKIN UNIVERSITY

ABSTRACT

FACULTY OF LORD ASHCROFT INTERNATIONAL BUSINESS SCHOOL

DOCTOR OF PHILOSOPHY

GREEN SUPPLY CHAIN MANAGEMENT DRIVERS/PRESSURES, PRACTICES AND PERFORMANCE IN CHINESE CONSTRUCTION INDUSTRY

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With the requirements of regulatory bodies, customers and business partners, Chinese construction sector have been driven to imitate and implement green Supply Chain Management (SCM) for their companies, to gain economic benefits and to become sustainable. This research aims to investigate and identify green SCM practices that can potentially help improve environmental and economic performance of organisations in Chinese construction sector, leading to improved sustainability. With data collected from 103 companies in Chinese construction industry, an exploratory factor analysis was conducted to derive groupings of green SCM pressures/ drivers, practices and performance. Analysis of variance and t-tests were introduced to assess the variations in green SCM pressures/drivers, practices and performance for different sized enterprises and different industry sectors. Using regression analysis, relationships between green SCM pressures/ drivers, practices and performance were examined. To gain in depth insight into the causal relationship among factors obtained from the empirical studies, two case studies were conducted. This research also explored and identified gaps existing between green SCM in Chinese construction industry and British construction industry through benchmarking exercise. The main findings from the empirical studies result reveal that: 1) Regulations and internal factors are considered as important green SCM drivers and pressures. Medium and large sized Chinese companies face higher regulatory pressures than small firms. 2) Case studies confirm that green SCM is not a new concept in Chinese construction industry. Companies have begun to change their focus from improvement in one supply chain entity to the entire supply chain. 3) Chinese construction companies seem to be more matured in their adoption of green procurement practices than companies in building material sector. 4) There is not any significant relationship between green SCM practices and performance since most of the enterprises just initiate implementing green SCM practices. Medium and large sized companies in Chinese construction industry have better economic performance than small sized companies. The results from the benchmarking exercise against British construction sector reveal that: 5) Green SCM implementation in British construction sector is more comprehensive and effective because customers and suppliers in Britain have more proactive involvement in adopting green SCM practices.

Key words: Green supply chain management; Construction industry; China

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Introduction

Business operations and changing individual consumption patterns over the last two decades have put our resources and environmental systems under risk, which resulted in increased carbon emission and climate change. To meet the needs for the present in terms of human and economic development, without compromising the quality of life of future generations, the sustainable development campaign was launched all over the world. Especially after China's entry into WTO (World Trade Organization), may result in higher environmental pressures/drivers for Chinese enterprises to refine environmental performance (Zhu and Sarkis, 2006). China is one of the top emitters of greenhouse gases, and China emits about 10.5 billion tonnes of carbon dioxide in 2014 (PBL Netherlands Environmental Assessment Agency, 2015). Being one of the top emitters of greenhouse in China, construction industry is subjected to a mandatory emissions reduction target. China agrees to a mandatory 20% cut in emissions by 2020 (Liu, 2015), which imposes heavy pressure for construction industry supply chain to reduce their carbon footprints. In the 12th Five Year Plan (FYP) of Chinese government, rolled out in 2011, new metrics and goals were established for reduction of carbon emissions per unit of GDP of 17% by 2015 over the 2010 level. The 12th FYP also includes aggressive targets for green buildings: A 65% reduction in energy consumption compared to 1980 building stock, an increase in the number of buildings that qualify for China's 3-Star sustainability rating, and a housing industrialization programme.

To achieve the ambitious targets set in the FYP, organisations in China are under huge pressure to green their regular practices, by integrating environment considerations into their daily operations and long-term business strategies. Every single organisation is an entity in a supply chain (SC) where products and service are sourced, manufactured, stored, distributed and consumed. Carbon emissions are produced by the whole SC, rather than by individual organisation. According to Carbon Trust (2006), carbon emissions are produced by human activities to grow the economy and satisfy human goals in obtaining goods and services. As a result, greening SCs has become increasingly important for organisations to reduce their carbon emissions and the negative impacts. China's State Environmental Protection Administration (SEPA) is enacted for emission control due to rapidly expanding wealth and prosperity (China Daily, 2011).

As a more systematic and integrated strategy that helps organizations achieve profit and market share objectives while reducing carbon emissions and raising ecological efficiency, the concept of green supply chain management (SCM) emerged in the late 1990s including green procurement and purchasing (Min and Galle, 1997; Gunther and Scheibe, 2006), environmental purchasing (Carter, Kale and Grimm, 2000; Zsindisin and Siferd, 2001), green logistics (Murphy and Posit, 2000), sustainable supply chain (Linton, Klassen and Jayaraman, 2007; Bai and Sarkis, 2010), sustainable supply network management (Young and Kielkiewicz-Young, 2001), demand and supply sustainability in the networks of corporate social responsibility (CSR) (Kovacs, 2004; Cruz and Matsypura, 2009), and supply chain environmental management (Sharfman, Shaft and Anex, 2009).

Being driven by different drivers or pressures, Chinese firms have started adopting green SCM giving special attention to environmental issues from different directions. Analysis of green SCM drivers and pressures from a Chinese industrial perspective follows limited research: Chan and Lau (2001) evaluated the motivational factors that influence green purchasing in Chinese firms in Shanghai and found the expectation of customer was a significant factor influencing green purchasing behaviour. Christmann and Taylor (2001) also found the expectation of foreign customer was an important factor driving green purchasing to be adopted by suppliers in Shanghai and Shenzhen. Zhu and Geng (2001) found Chinese state-owned enterprises encouraged their suppliers to adopt and implement environmental activities through integrating environmental issues into supplier selection. Zhu, Sarkis and Geng (2005) found Chinese enterprises had increased their environmental awareness under the pressures from regulations and competitors in the market. However, this awareness had not been translated into strong adoption of green SCM. Zhu, Sarkis and Lai (2007) analysed pressures for green SCM from a Chinese automobile industry's perspective and identified regulative, market, suppliers and internal pressures, and the findings revealed that Chinese automobile industries were facing high and increasing regulatory and market pressures. While in the meantime these industries were also facing strong internal drivers for green SCM practice adoption. Chan, et al., (2012) found foreign-invested enterprises operating in China were facing high pressures to establish long-term relationships with their foreign investors who pressurised Chinese enterprises to implemented green SCM practice. Construction industry accounts for around 9% GDP of China (National Bureau of Statistics of China, 2016), it is a pillar industry of China's economy. However, there is a lack of research investigating the pressures experienced by Chinese construction industry on green SCM. To bridge the gap in the under researched area, the initial objective of this study is to identify pressures faced by Chinese construction industry implementing green SCM.

Green SCM has been widely studied in the last two decades. The impacts of adoption of green SCM practices on firm performance has so far been inconclusive. Zsidisin and Hendrick (1998) reported that activities such as product design, investment recovery, hazardous materials control, and environmental purchasing has all had positive influence on environmental performance. The findings are supported by the interviews with managers in the US, UK and German enterprises. It is believed that supports from the mid-level managers was a key factor of internal environmental management which for improving organisational performance as a whole in Germany (Carter, Ellaram and Kathryn, 1998). Support from senior management support also play a significant role on improving firm performance in the U.S. and Germany (Carter, Kale and Grimn, 2000). Government driven initiatives were identified as important elements supporting environmental improvement in small and medium-sized enterprises in the UK (Holt, Anthony and Viney, 2001). Green SCM practices such as internal environmental management, external green SCM, eco-design and investment recovery were identified to improve enterprises' environmental performance in Chinese manufacturing and processing enterprises (Zhu and Sarkis, 2004). If the present study finds a positive causal relationship between green SCM implementation and performance, the same can act as a motivating factor for supply chain managers in Chinese construction industry to proactively adopt green SCM practices. This research is one of the earliest studies to conduct survey to assess the adoption of green SCM practices in Chinese construction industry and explore the relationship between green SCM practices and performance.

Implementations and activities of green SCM do not end at the boundary of organisations, and there is a need to investigate green SCM across the whole chain (Zhu, Sarkis and Geng, 2005), which encompasses product stewardship, extended producer responsibility, product life cycle analysis, operational life cycle analysis, industrial ecology and industrial eco-systems. It is critical for every entity in the SC to take actions on greening their operations to achieve the green SCM. In a board sense, Zaklad, et al., (2004) and Carter (2000) also think green SCM falls within the literature of sustainability and ethics which incorporates the economic and social influences. Analysis on green SCM performance in Chinese industrial sector is under researched: Zhu and Sarkis (2004) used economic and environmental performance as the criteria to assess the relationship between green SCM practices and performance. Economic performance is measured against the decrease of fine for environmental accidents, fee for waste treatment and discharge, cost for energy consumption, cost for material purchasing, increase of operational cost and investment; while environmental performance is assessed in terms of reduction of solid waste, waste water and air emission. The research was conducted as an empirical study with Chinese manufacturing and processing companies. In addition to the economic and environmental performance, improvement in flexibility, delivery, quality, cost and customer satisfaction was also considered as one of the green SCM performance criteria (Chavez, et al. 2016) in Chinese automotive manufacturers. However, there is little research identifying green SCM performance metrics for Chinese construction industry's green SCM.

Although the sustainability has been investigated for a wide range of industrial sectors in China, including automobile (Zhu et al, 2007), steel industry (Zhang et al, 2009), energy and resources (Shen et al, 2005), agriculture (Cai and Smit, 1994), etc., there is virtually no rigorous research on environmental sustainability issues facing the construction or real estate development supply chain in China. The increased carbon emission from estate buildings is an issue that has reached public consciousness more and more. There is an emerging concern about the potential impact of increased carbon emissions on environment, ecological system and public health. This research aims to investigate and identify green SCM practices that can potentially help improve environmental and economic performance of organisations in Chinese construction sector, leading to improved sustainability. This research focuses on the current state of affairs in Chinese construction supply chain while highlighting issues that are helping or hindering organizations in the construction supply chain to adopt and implement green practices.

Five research objectives are constructed to fill the literature gap and achieve the research aim:

1) To investigate and identify essential pressures/drivers for implementation of green SCM, key success factors of green SCM practices and key performance indicators for successful implementation of green SCM practices in Chinese construction sector by factor analysis approach;

2) To evaluate and determine if construction organisations differ in the green SCM pressures/drivers, practices and performance with an emphasis on their sizes and nature of business by ANOVA and t-test approach;

3) To investigate causal relationships among green SCM pressures/drivers, practices and performances by correlation and regression analyses approach;

4) Through two cases studies, to gain an in-depth analysis on how construction organisations address the green SCM pressures/drivers, practices and performance;

5) To benchmark Chinese green SCM practices against the British practices in construction sectors, identify gaps and best practices, and deliver grounded recommendations for future practice.

To explore the environmental sustainability issues, the empirical work investigated a large sample of organisations in the construction supply chain, with regard to their operations on environmental sustainability issues. The empirical results provide an overview of the general industry and its practices, and will help inform the discussion on managerial, policy, and research directions for environmental sustainability in the Chinese construction supply chain.

The structure of the paper is as follows. In Chapter 1, the researcher reviews the relevant literature, and developed the research framework and posited hypotheses of this study in Chapter 2. In Chapter 3, research methodology is discussed including research design administration of questionnaire, process of case study and benchmarking method. Chapter 4 discusses data collection and collation, and tools and techniques for data analysis; it also presents the results of data analysis along with discussion on the results. Chapter 5 and Chapter 6 present applications of case studies and benchmarking, Chapter 7 discusses the major findings from empirical analysis and case studies. The implications for supply chain managers and the governments are presented in Chapter 8. Finally, concluding remarks and directions for further research are presented in Chapter 9.

Chapter 1 Literature Review

Based on a review on the extant literature related to green SCM concepts, as well as product and operational life cycles, we identify the essential pressures/drivers on adopting/implementing green SCM practices, a list of green SCM practices and key performance indicators for successful implementation of green SCM practices. Drivers on green SCM adoption and implementation are identified as regulative, market and corporate internal pressures. Green SCM practices include corporate internal environmental management, green procurement, green distribution and reverse logistics, and government involvement. Two types of green SCM performance are adopted, i.e. environmental performance and economic performance.

1.1 Green SCM conception

Traditional SC is defined as the extent of logistics, while a more contemporary concept defines SC as the chain that 'contains all operations related to the transformation and flow of information as well as flow of goods from the stage of raw material, through to the end user' (Handfield and Nichols, 1999). SCM is a developing theory of management, and was introduced as a result of increased competition in international markets (Seuring, 2001). To achieve the sustainable competitive advantages, SCM improves the inter-relationship and corporation between SC parties, and integrates the cooperation across the supply chain.

Green SCM meets with demand on pollution abatement and energy conservation to enhance operational efficiency, waste reduction, or to purchase environmental superior products (Zhu and Cote, 2004). One of the aims of green SCM is to balance the economic performance with issues of environment. As such, a wide range of initiatives for green SCM have been introduced to SC entities, consisting of packing for re-manufacture and re-use, developing reverse logistics system to recover product, providing training to build supplier's capacity of environmental management, and supervising suppliers for environmental performance (Zhu, Sarkis and Geng, 2005). Effective implementation of green SCM enable organisations to not only gain environmental benefits but also to generate economic profits. Green SCM is considered as a relatively advanced management practice to generate environmental benefits; it is also viewed as a new philosophy of environmental management which incorporate the entire SC (Narasimhan and Carter, 1998).

In application, green SCM can be utilised in parallel, or by overlapping with other environmental approaches, such as environmental management system and cleaner production system, to further enhance the green performance. The key elements needed for developing a green SCM approach (Nagel, 2000), include: 1) the attention to production process; 2) the attention of material content of components and products; 3) an awareness in the relationship of customer-supplier; 4) cost effectiveness; 5) the concentration on environmentally technological innovation; 6) the internal direct driver of green SCM; and 7) a strategy driven program of green SCM. It is recommended that product and operational life cycle could be regarded as more tactical set of organisational factors that necessarily affect impact both internal and external green SCM in organisations (Sarkis, 2003).

1.2 Product and operational life cycle influences green SCM

The impacts of environment exist at all phases of product life cycle (Zhu, Sarkis and Geng, 2005). The product life cycle positioning of a product necessarily affects the green SCM in an organization. A typical life cycle of product involves four stages (Glessner and Gillis, 2012), including 1) an introduction phase of product which is characterised by the investment in research and development of product; 2) a growth phase of product which is characterised by the increasing logistics channels and production capacity; 3) a maturity phase of product in where the cost and process efficiencies are implemented typically; 4) and a decline phase of product which is focusing on the divestment of product.

In the introduction phase of a product, the product design for environmental issues can play an important role on the environmental performance of such as product. While in the mature phase and decline phases, efficient reverse logistics system and the process of improvement will influence the organizational environment performance (Sarkis, 2003). Environmental management decisions become more complex for the multiproduct analysis. Depending on the products' life cycle maturity, there should be differentiated green SCM strategies within the product portfolio (Aitken, Childerhouse and Towill, 2003).

Operational life cycle of the organization is regarded as more tactical set of organisational factors that impact both internal and external SCM (Ninlawan, et al., 2010). The main components of operational life cycle include 1) procurement, 2) production, 3) distribution, 4) reverse logistics and 5) packaging.

The procurement decision will impact the green SC, through the type of purchased materials (reusable or recyclable), or through the selection of vendors (Ghobakhloo, et al., 2013). Procurement department needs to decide whether to outsource the components or processes for environmental purposes if outsourcing is to be used. ISO 14000 certification becomes selection criteria, as it indicates the vendors meet the environmental requirements and their environmental risks are lessened (Zsidisin and Hendrick, 1998).

The production process impacts the green SC in many ways (Sarkis, 2003), including 1) how well the processes are designed for the waste prevention, 2) capabilities to integrate remanufactured or reusable components into the systems, and 3) a capability process to reuse the materials. Since the production is usually the internal focus of an organisation, the process of production becomes the function that enables the advancement and the innovations of the environmentally sound technological process (Gillett, 1993), which allows the organisation to be more directly observing the benefits of the new innovated process.

Operation networks of transportation and distribution are also significant characteristics of operation that can influence the green SC (Ninlawan, et al., 2010). Decisions of just-in-time policies, control system, mode of transportation, and distribution outlet locations, cannot only impact the forward logistics network, but also influence reverse logistics network (Zsidisin and Hendrick, 1998; Zhu, Sarkis and Geng, 2005). The operation of distribution is most closely tied to the customers' requirements and characteristics. Therefore, involvement of customer in the design and development of distribution system seems to provide the efficient and effective distribution network (Sarkis, 2003).

The operation of reverse logistics may be the least developed functions of operation (Zhu, Sarkis and Geng, 2005). The reverse logistics primarily focus on the return of reusable and recyclable materials and products into the forward SC from the environmental perspectives. The typical activities in a reverse logistics are 1) collection, 2) separation, 3) densification, 4) transitional processing, 5) delivery, and 6) integration (Pohlen and Farris, 1992). To have a fully operational reverse logistics system, there need to be not only a network for the collection process, but also a number of the processes and systems.

Packaging has the strong relationships with other functions of life cycle of operation. The key features of packaging in terms of materials, shape and size can influence distribution (Sarkis, 2003). Along with rearranged from loading patterns, better packaging can 1) reduce the amount of handling required, 2) increase utilisation of space in the trailer and warehouse, and 3) reduce materials usage. However, adoption of returnable packaging requires an effective channel of reserve logistics and a strong relationship with customers and suppliers. The efficiency in packaging directly affects the environment.

Product and operational life cycle analyses do not end at the boundary of organisations, and there is a need to investigate how to balance environmental and economic performance across the whole chain. It is critical for every entity in the SC to take actions on greening their operations to achieve the green SCM (Zaklad, et al., 2004). In a board sense, organisations facing pressures from community, regulatory bodies, and competitors are more active in implementing activities for sustainability, to improve both economic and environmental performance.

1.3 Green SCM drivers/ pressures

Balancing environmental and economic performance is increasingly becoming important for the organisations facing community, regulatory, and competitive pressures. Several studies have identified potential groups that can be regarded as explanations as to why green SCM is adopted. For example, Henriques and Sadorsky (1999) identified critical environmental stakeholder groups, including 1) organizational stakeholders who have direct financial impacts on organisations, 2) regulatory stakeholders, which have the capacity to set regulations and standards, 3) environmental organisations and community groups, which can mobilise public opinion against or in favour of environmental policies of organisation. Different types pressures are incurred all over the world, thus, organisations have improved environmental control to cope with the pressures and drivers on green SCM.

- Regulations

The coercive driver refers to the influence imposed by those in power such as government agencies and the regulatory regime, which can also be regarded as the regulative pressures (Zhu and Geng, 2013; Rivera, 2004). Regulatory stakeholders are identified by Henriques and Sadorisky (1999) as one of the critical environmental stakeholder groups, which either have the ability to influence governments to set regulations or set regulations on their own. This pressure is imposed on companies internally, but the way companies deal with the pressure varies significantly. Spanish industrial firms (including food, textile, wood, stationary, chemistry, metal-mechanical, transport and electronics) successfully turned the external pressure into opportunities for driving the environmental activities (Del and Jaunquera, 2003). Chinese automobile industry has faced to challenges of environmental barriers in the EU, U.S., Japan and Korea (Yang, 2010). Since China's entry into the WTO (World Trade Organisation), some countries had put forward the environmental requirements for the dyes and fabrics of clothes imported from China, and requested a certification of wood products imported from China (Zhu, Sarkis and Geng, 2005). If Chinese organisations do not meet the associated international environmental standards, there would be penalties imposed on these organisations. The global environmental issues force big countries like China to take actions on meeting environmental requirements. As such, Chinese state-owned firms have developed environment management system, to be compliant with environmental law and improve their environmental performances. Their environment management systems are independently certified to the international standard ISO 14001 (Zhu and Geng, 2001). Kyoto Protocol commits companies to reduce greenhouse gas emissions, and imposed further pressures on the industry that emits greenhouse gas (Zhu and Sarkis, 2006). With the introduction of the environmental regulations in China, Chinese manufacturers are encouraged to reduce, reuse and recycle materials; and they are also required to label the toxic content.

The relevant items on regulative pressures included in the study are as following: environmental regulations, domestic regulations, and foreign regulations.

- Market

The normative driver comes from the external stakeholders such as customers, and this driver usually drives organisations to implement the environmental activities. Organisational stakeholders such as customers can have the direct financial impact on the organisation. Chan and Lau (2001) point out that the customers increasingly have enhanced the environmental awareness and prefer the 'green' products. The translations of green procurement intention to relevant behaviour had been observed more and more among customers (Chan and Lau, 2001). For example, Christmann and Taylor (2001) claim that sales and export to foreign customers are the major drivers for environmental activities of organisations. In the process of globalisation, customers increase raise demands on Chinese organisations, requiring them to meet environmental standards. The global pressure usually surpassed the domestic requirements. Some countries such as U.S. and Japan have put forward different environmental requirements on garment imported from China (MFTECO, 2003). Leading organisations from developed countries not only evaluate their direct suppliers but also assess their second-tier suppliers. As such, many Chinese companies acquire ISO 14000 certification, under the SC pressure in environmental management, imposed by their foreign clients (Zhu and Sarkis, 2006).

Green SCM pressures from foreign customers is driving Chinese firms to self-regulate and especially acute in China. For example, due to the green barriers to Chinese exports, about 20 billion US dollars of commodities were rejected by developed countries for exporting between 1997 and 1999 (News Agency of Xinhua, 2001). Although the green procurement behaviours of Chinese customers lag behind those of the customers living in developed countries, younger Chinese customers are increasing their environmental awareness and prefer environmental friendly products (Chan and Lau, 2001; Lo and Leung, 2000). The demands from customers on green products motivate organisations to incorporate environmental activities into their operation activities (Kagan, Gunningham and Thornton, 2003). For example, the building material manufacturer such as Ecocative uses natural resin and cellulose based materials such as flax, canola and hemp to manufacture replacement for fibreboard, plywood and particleboard (Ecovativedesign, 2015). Therefore, the coercive drivers such as environmental regulations and normative drivers like market or customer are considered as drivers to the green SCM practices.

Items related to market pressures have been classified as domestic customers' expectations on green products and foreign customers' expectations on green goods.

- Internal factors

The mimetic drivers can also be considered as one of the drivers of environmental management practices. It occurs when organisations mimic the practices of successful competitors when responding to the natural environmental issues (Bergh, 2002). Competitors also impose pressures to implement environmental activities (Carter and Carter, 1998). Chinese companies have gained benefits by learning from clients and competitors. In Zhu and Liu's (2010) study, they find Chinese companies learned good environmental practices from leading competitors in developed countries, and implement them proactively in China. Their products therefore meet environmental requirement, which enable them to win the bidding and become main suppliers to many FDI (foreign direct investment) and joint venture companies. Zhu and Geng (2001, 2013) support that mimetic driver motivates organisations to imitate the activities of their successful competitors, such a creating their environmental images, addressing environmental policies and missions, and taking liability for safe disposal hazardous materials.

This mimetic driver can be considered as the internal factor that plays as an important role in driving organisation environmental practices.

The following items on corporate internal pressures have been investigated in this study: green image, environmental policies and/or missions, and liability for disposal of hazardous materials.

The detailed list of green SCM pressures is summarised in Table 2.1, including: environmental regulations, national regulations, foreign regulations, domestic customers' expectations, foreign customers' expectations, green image, environmental policy, liability for disposal hazardous materials.

1.4 Green SCM practices

Proactive companies have greater level of implementation of green SCM practices, such as green purchasing, internal environment management, and eco-efficiency to enhance sustainable performance and corporate image (Zhu and Geng, 2001). Internal environmental management is key to improve the environmental performance, which consists of a set of activities to achieve environmental targets of organisation, as either imposed by legislation or defined by managers (Rao, 2002). Green procurement focuses on as to whether the purchased materials are reusable or recyclable, or have been recycled already (Sarkis, 2003). It allows organisations to offset environmental and financial risks, rather than inheriting it from suppliers (Zsindisin and Siferd, 2001; Carter, Kale and Grimm, 2000). Green distribution and reverse logistics have important impacts on green SCM (Zhu, Sarkis and Geng, 2005). The operation of green distribution is most closely tied to the customers' requirements and characteristics. European and United States companies have considered reverse logistics as an important aspect for green SCM (Zsidisin and Hendrick, 1998). Government involvement in green SC has shifted emphasis from pollution control to the product life cycle (Lee, 2008). Activities of government involvement range from direct financial and technical support to indirect infrastructure development and encouragement with tax-cut incentives for environmental complexes (Holt, et al., 2001).

- Internal environmental management

The internal environmental management is a key to improve the environmental performance. The middle and top management should be totally committed to ensure the complete environmental excellence due to the support from managers is the necessary driver for the successful implementation and adoption of most activities, programs, technology, and innovations (Carter, Kale and Grimn, 2000). Furthermore, the mid-level managers' support is important for successfully implementing the internal environmental management (Carter, Ellram and Kathryn, 1998). The positive relationship and communication in the environment management (Bowen, et al, 2001). The perceptions of mid-level managers of the environmental proactivity can lead to a positive environmental outcome (Aspan, 2000). Cooperation between different departments in organisations is also important in the successful environment and business relationship (Zhu and Sarkis, 2004). In the theory of operational life cycle of the organisation, as an internal environmental practice, the process of production impacts the green SC in many ways (Sarkis, 2003), including 1) how well the processes are designed for the waste prevention, 2) the capabilities of integrating remanufactured or reusable components into the system, 3) and the capability to reuse the recycled materials. Gillett (1993) states that the process of production equipped with the environmentally sound technological innovations is most advanced. Introducing environmental innovation to the production process would enhance the environmental friendliness of the finished product and bring benefits to the organisation, such as improved corporate image, increased market share, increased profits etc.

The items on internal environmental management practices included in the study are following- supports from senior level management team for environmental activities, commitment from mid-level managers for environmental actions, inter-departmental cooperation for environmental improvement, and improvement of production process.

- Green procurement

On the other side, in external green SCM practices, the decisions of procurement focus on if the purchased materials are either reusable or recyclable, or have been recycled already. ISO 14000 certification is important criteria used in supplier selection phase (Zhu, Sarkis and Geng, 2005). Additionally, the suppliers with lower risks on environment are preferred. Lessing or reducing risks on environment would help suppliers to gain benefits in the long term (Sarkis, 2003). And whether to the components or processes outsourcing may be a concern for the purchasing department. The major factors influencing supplier selection are summarised as ISO 14000 certification, environmental audit for internal management of supplier, supplier cooperation for environmental objectives, and the environmental purchasing requirements (Zsidisin and Hendrick, 1998).

The relevant items on green purchasing practices included in the study are the following- cooperation with suppliers for environmental objectives, ISO 14000 certification for suppliers' selection, and environmental requirements for purchased items.

- Green distribution and reverse logistics

Environmental practices such as green distribution and reverse logistics emergently had the important external and internal impacts on green SCM. The reverse logistics primarily focus on the return of reusable and recyclable materials and products into the forward supply chain from the environmental perspectives (Sarkis, 2003). Moreover, Pohlen and Farris (1992) identified the reverse logistics process in terms of 1) collection, 2) separation, 3) densification, 4) transitional processing, 5) delivery, 6) and integration. Therefore, not only the processes and systems need to exist for the reverse logistics, but also does there should be a network for the collection process of reverse logistics in the channel of reverse logistics (Zsidisin and Hendrick, 1998). The requirements can vary among the phase of reverse logistics depending on the type of product, industry, and organization.

Additionally, operation networks of distribution are also significant characteristics of operation that can influence green SC. Just in time policies, control system, modes of transportation and distribution outlet locations can not only influence forward logistics network, but also impact on reverse logistics network (Madaan and Wadhwa, 2007). The operation of distribution is most closely tied to the customers' requirements and characteristics. Therefore, involvement of customer in the design and development of distribution system seems to provide the efficient and effective distribution network. For instance, linking the location decisions to suppliers and customers can improve just in time systems (Bentz et al., 1999). Furthermore, the characteristics of packaging in terms of 1) materials, 2) shape, 3) and size can influence the distribution since their effect on the transport items characteristics (Bentz et al., 1999). Along with rearranged loading patterns, the better packaging can 1) reduce the amount of handling required, 2) increase utilization of space in the trailer and warehouse, 3) and reduce materials usage (Zhu, Sarkis and Geng, 2005). They assert that encouraging the returnable packaging requires an effective channel of reserve logistics and a strong relationship with customers and suppliers. Just in time special packaging should also be required to minimise the waste of packaging, and the efficiency in packaging directly affects the environment.

Green distribution and reverse logistics are two emerging environmental practices that have both external and internal influence on green SCM. Chinese government has varied the policy from focusing on resource subsidies to releasing taxes for the raw resources in terms of natural gas and coal with improving better system and process design and investment recovery. Lewis and Gretsakis (2001) conclude that when product environmental performance is largely determined and the process and materials are selected, most of the environmental impacts are locked at the phase of design no matter where in the product life cycle a process or product lines.

Items related green distribution and reverse logistics practices have been identified as follows- recovering from excess inventories or materials, cooperation with customers for environmental transportation, and reusing used materials or scrap.

- Government involvement

The role of the government in green SC has been getting more important. Governments have become involved in green SCM initiatives as environmental regulations shift emphasis from pollution control to the life cycle of the products. A typical life cycle of product involves four stages: 1) an introduction phase of product which is characterised by the investment in research and development of product; 2) a growth phase of product which is characterised by the increasing logistics channels and production capacity; 3) a maturity phase of product in where the cost and process efficiencies are implemented typically; 4) and a decline phase of product which is focusing on the divestment of product (Aitken, Childerhouse and Towill, 2003). One factor of the government involvement could affect the SCM is the product life cycle positioning of products (Lee, 2008). Government strategy includes a range of scope from financial and technical support to indirect encouragement and infrastructure development, such as undertaking the energy efficiency best practice campaign to provide free advice and technical support, bringing awareness of green SCM practices through manuals and guidebooks, developing the best practices of green supply chain, and other government driven initiatives (Holt, Anthony and Viney, 2001). Product life cycle phases could influence the green SC necessarily (Sarkis, 2003). For instance, the product is more impacted by the design, and the design for the environmental issues can play an important role in the introduction phase. Moreover, the efficient reverse logistics system and the process improvement can influence the organizational environment practice in the mature phase and decline phase of product. In addition, Sarkis (2003) suggests that the environmental management decisions become more complex for the multiproduct analysis. However, there would be some different life cycle of product development and strategies of environment which can be depend on the maturity of product life cycle within the product portfolio. Government involvement is an important trigger for environmental innovations and assisting the companies to move towards greener enterprises.

The items on government involvement practices that have been included for the study are the following- infrastructure for facilitating environmental practices of firms, providing environmental information and technical assistance to companies, and popularising knowledge of environmental management in enterprises.

Based on the literature review, the following items on green SCM practices have been adapted and included for the study (as shown in Table 2.2), including: commitment from mid-level management, commitment from senior level management, inter-departmental cooperation, improvement of manufacturing process, cooperation with supplier, environmental requirement, ISO 14000 certification, excess inventory and material, environment friendly transportation, used material and scrap, technology utilisation, infrastructure, assistance from government, and knowledge popularisation.

1.5 Green SCM performance

Performance is a measure for evaluating the degree of the objective attainment of organisations (Chien and Shih, 2007; Draft, 1995). Environmental performance indicators consist of management performance indicators and operative performance indicators. Management performance indicators concern the contribution of organisational administration to the overall environmental management, whereas operative performance indicators are mainly related to the evaluation of real environmental aspects of organisation, waste and emission production, energy management and consumption of materials (Papadopoulos and Giama, 2007). Green SCM practices encompasses diverse initiatives to minimise or reduce the adverse environmental impacts of operations of organisations. Environmental performance is defined as the environmental effects that organisational practices have on the natural milieu (Sharma and Vredenburg, 1998), including reduced energy consumption, reduced use of hazardous materials (Hervani, Helms and Sarkis, 2005), reduced air emission (Zhu, Sarkis and Lai, 2007), and reduced solid/ liquid waste (De Giovanni and Vinzi, 2012).

Green SCM practices encompasses diverse initiatives to minimise or reduce the adverse environmental impacts of operations of organisations, which may also bring about some economic benefits for organisations. Many organisations look upon green SCM as involving trade-offs between environmental and economic performance (Klassen and McLaughlin, 1996). The economic performance is influenced by environmental performance in variety of ways. The factors driving the competitive advantages through environmental performance are identified as 1) business efficiency, 2) regulatory compliance, 3) risk management, 4) and market expectations (CBI, 1994). Improved environmental performance could lead to increased market share and improved revenue (Rao and Holt, 2005). The reduced or minimised hazardous and non-hazardous waste results in reduced operating costs, higher productivity and improved efficiency (Zhu, Sarkis and Lai, 2007). Extant studies have found a number of economic benefits as a result of integration of environmental issues, including improvements in public relations, increases in market share, cost saving and improvements in organisational efficiency, product quality improvement, and increase in profit margin (Zhu, Sarkis and Geng, 2005). While economic performance and competitiveness have been well researched in the dimensions of organisational financial status and operational performance, measures like organisational growth, market share, efficiency, product quality, and productivity receive less attention.

This study measures green SCM performance using two metrics, i.e., environmental performance and economic performance. Items on green SCM practices have been adapted from literature and listed in Table 2.3, including, reduction of solid/ liquid waste, reduction of air emission, reduction of consumption of hazardous materials, reduction of consumption of energy, increase of profit margin, improvement of corporate image, increase of investment, increase of market share, increase of sales, increase of efficiency, improvement of productivity, improvement of product quality, reduction of cost for material procurement, reduction of fees for waste treatment or discharge.

Chapter 2 Research Framework and Hypotheses

Green SCM is designed to incorporate environmental considerations into strategic decision making at each stage of materials management and logistics functions to enhance operational efficiency, waste reduction, or to purchase environmental superior products (Zhu and Cote, 2004; Handfield, Sroufe and Walton, 2005; Simpson and Power, 2005). Definitions on green SCM vary under different frameworks or context. In institutional theory, green SCM has been defined as the environmental management relationship between organisational actions and normative, coercive and mimetic pressures/ drivers (Kilbourne, Beckmann and Thelen, 2002; Aerts, Cormier and Magnan, 2006; Ball and Craig, 2010). Coercive pressure refers to the influence imposed by those in power such as government agencies and the regulatory regime (Scott, 2001); normative driver usually drives organisations to implement the environmental activities (Zhu and Geng, 2013); mimetic pressure occurs when organisations mimic the practices of successful competitors when responding to the natural environmental issues (Bergh, 2002).

The strategic decision framework for green SCM describes some important elements of green SCM including influences and relationships of the environmentally conscious business practices and organisational performance measurements (Sarkis, 2003). The researcher focuses on four types of green SCM practices, i.e., internal environmental management, green procurement, green distribution and reverse logistics, and government involvement for the following reasons: 1) these practices have received greater attention in manufacturing companies in China (Zhu, Sarkis and Geng, 2005; Zhu, Sarkis and Lai, 2007); 2) these practices represent the key activities in a SC, including procurement and distribution; 3) these practices symbolise the green management systems in an organisation, such as environmental management system; and 4) these practices indicate the level of government involvement which is key to the success of any environmental activity. These institutional pressures/drivers, environmentally influential organisational practices and organisational performance measurements serve as the foundation for a framework for selecting systems by the organisation that will aid in green SCM.

The research framework, shown in Figure 2.1 is developed to examine the relationships between green SCM drivers, practices and performance, i.e, how various factors (regulation, market and internal factors) motivate green SCM practices, and how green SCM practices (internal environmental management, green procurement, green distribution and reverse logistics, and government involvement) influence green SCM performance (environmental and economic). It examines if and how green SCM drivers/ pressures influence green SCM practice adoption/ implementation, and if these implications are translated into performance improvement. Green SCM pressures/drivers items were based on existing literature that addressed various of elements of green SCM (e.g. see Henriques and Sadorisky, 1999; Chan and Lau, 2001; Christmann and Taylor, 2001; Zhu and Geng, 2001; Zhu, Sarkis and Geng, 2005) and input from expert opinion (see Questionnaire design and development). Practices dimensions were developed based on previous literature (e.g. see Carter, Ellram and Kathryn, 1998; Zsidisin and Hendrick, 1998; Carter, Kale and Grimn, 2000; Holt, Anthony and Viney, 2001; Zhu and Sarkis, 2004; Zhu, Sarkis and Geng, 2005) and input after consultation with practical expert (see Questionnaire design and development). Performance items were based on a review of literature (e.g. see Zhu and Sarkis, 2004; Hervani, Helms and Sarkis, 2005; Rao and Holt, 2005; Zhu, Sarkis and Lai, 2007; Tsai and Hung, 2009; De Giovanni and Vinzi, 2012). Based on the institutional theory, strategic decision framework for green SCM and other existing literature, the researcher structures the research framework, to illustrate that green SCM drivers/ pressures are key determinants of green SCM practice adoption/ implementation, which help organisations meet environmental requirements. The outcomes from implementing green SCM practices is improvement in both economic and environmental performance.

Previous literature has seen mixed results on the relationships between green SCM drivers/ pressures, practices adoption and performance. Several studies have examined these relationships and achieved mixed results which vary with individual study and the industry sector examined. Some are conclusive with directly positive relationships (Del and Jaunqura, 2003; Zhu and Sarkis, 2006; Christmann and Taylor, 2001), while some are inconclusive or negative (Wagner, Schalteger and Wehrmeyer, 2001; Bowen, et al., 2001). Most of these researches was conducted from empirical, conceptual and analytical perspectives. There are no exact conclusions on the relationships among green SCM drivers/pressures, practices and performance, so the researcher sets up research framework and posits hypotheses in this study based on the exiting literature.

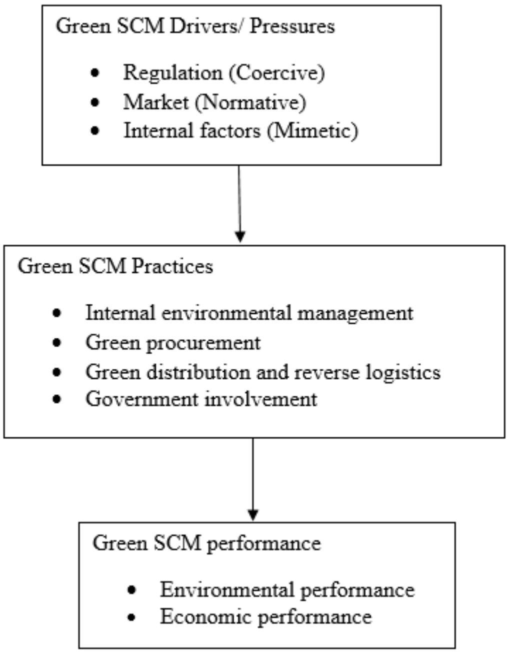


Figure 2.1 Research Framework

2.1 Green SCM drivers/ pressures for practices adoption

The increasing pressure for the sustainability of environment imposes an expectation on organisation, requiring them to implement a sustainability strategy to reduce or offset the environmental impacts of their services or product (Lewis and Gretaskis, 2001). Pressures generally arise from regulative bodies, market and competitors, which are incurred all over the world. Institutional theory posits the environmental management activities are motivated by three drivers, including normative, coercive and mimetic (DiMaggio and Powell, 1983). The three types drivers can be further defined as, drivers from government agency or regulatory bodies (coercive), environmental concerns (normative), and pressures from competitors (mimetic). In China, the issues associated with green SCM have become more critical (Zhu, Sarkis and Geng, 2005). Although the country is developing its economy speedily, China however faces substantial environmental burdens (Rao, 2002). China has increasingly become industrialised and has been used as the point of end of life product disposal for the developed country and multi-national organisation. Due to the increasing environmental burden on developed countries, the end of life products is shipped to developing countries such as China where there is no tool or infrastructure available to deal with the disposed products (Puckett and Smith, 2002). The initial objective in this research seeks to determine whether companies in Chinese construction industry are feeling these pressures/drivers for green SCM practices adoption. The hypothesis that is evaluated with empirical data is as follows:

Hypothesis 1a: Companies in Chinese construction industry are facing significant pressures to adopt green SCM pressures that arise from a variety of sources.

However, organisations are not exposed to the same extent or to the same type of pressures for implementation of green SCM practices (Zhu and Sarkis, 2006). Size is the natural logarithmic transformation of the number of full-time employees (Dean and Snell, 1991). Large and medium sized companies seem to encounter greater pressures on environmental protection than small ones who are generally reactive to the national ecological strategy (Revell, 2007; Zhu, et al., 2011). Small and medium sized companies are generally reactive to the national ecological strategy, but large sized enterprises with stronger environmental commitment are better motivate proactive environmental management (Roy and Therin, 2008). In addition, some industry sectors are more domestic focused whereas other industry sector is more global orientation and thus will have different pressures for adopting green SCM practices. For example, construction sector is mainly domestically oriented whereas building material sector is more globally focused and thus will have differing domestic and international motivations and pressures for incorporating green SCM practices. With the international pressures for reducing greenhouse gas emissions, there may be differing and increased pressures on building material sector that is traditional heavy emitters of greenhouse gases. Thus, two hypotheses are posited as follows:

Hypothesis 1b: The level of green SCM pressures/drivers is different in small, medium and large sized companies in Chinese construction industry.

Hypothesis 1c: The level of green SCM pressures/drivers is different in Chinese construction sector companies and building material sector companies.

Chinese companies have experienced increasing environmental pressures from the government and customers while recognising both environmental and economic benefits to green their SCs (Zhu and Sarkis, 2006; Zhu, Sarkis and Geng, 2005). As such companies in China begin to proactively implement green SCM strategies to reduce negative impacts on environments. Zhu and Sarkis (2006) support Chinese companies acquire ISO 14000 certification to meet the expectations from the foreign clients. Success in addressing environmental issues can not only provide new ways to add value to the business, but also provide new opportunities for competition (Hansmann and Claudia, 2001). As such in this research pressures from regulations and market are considered as important drivers to the green SCM practices. Apart from pressures, one of the major drivers on implementing green SCM practices is financial incentive. Christmann and Taylor (2001) claim that sales and export to foreign customers are the major drivers for environmental activities of organisations.

The pressures from corporate internal factors can also be considered as one of the drivers on environmental management practices. Approaches like environmental management system and cleaner production have been implemented as green SCM practices reactively to be compliant with regulatory requirements (Zhu, Sarkis and Lai, 2007). Environmental management system has been identified as an important source of competitive advantages that include the quality advantage (Narasimhan and Schoenherr, 2012), business efficiency, regulatory compliance (Walker, 2008), cost reduction and differentiation (Maria, Lopez-Gamero and Molina-Azorin, 2009) through optimizing environmental performance. Zhu and Liu (2010) find Chinese companies learned good environmental practices from leading competitors in developed countries, and implement them proactively in China. Zhu and Geng (2001, 2013) support that corporate internal factors motivate organisations to imitate the activities of their successful competitors, such a creating their environmental images, addressing environmental policies and missions, and taking liability for safe disposal hazardous materials. In summary, pressures from regulation, market and corporate internal factors motivate organisations to implement and promote their environmental practices (Zhu, et al., 2010). Institutional theory posits the environmental management activities are motivated by normative, coercive and mimetic pressures that come from regulations, market and internal factors of organisations (Kilbourne, Beckmann and Thelen, 2002; Aerts, Cormier and Magnan, 2006; Ball and Craig, 2010). Organisations have improved environmental control to cope with the pressures and drivers on green SCM. Thus, hypotheses are posited as follows:

Hypothesis 1d: Companies with higher levels of green SCM pressures/drivers are associated with higher levels of levels of internal environmental management practices in Chinese construction industry.

Hypothesis 1e: Companies with higher levels of green SCM pressures/drivers are associated with higher levels of levels of green procurement practices in Chinese construction industry.

Hypothesis 1f: Companies with higher levels of green SCM pressures/drivers are associated with higher levels of levels of green distribution and reverse logistics practices in Chinese construction industry.

Hypothesis 1g: Companies with higher levels of green SCM pressures/drivers are associated with higher levels of levels of government involvement practices in Chinese construction industry.

2.2 Relationships between green SCM practices and performance

Performance is a measure for evaluating the degree of the objective attainment of organisations (Chien and Shih, 2007; Draft, 1995). Green SCM practices encompasses diverse initiatives to minimise or reduce the adverse environmental impacts of operations of organisations. Internal environmental management is key to improve the environmental performance, which consists of a set of activities to achieve environmental targets of organisation, as either imposed by legislation or defined by managers (Rao, 2002). Green procurement focuses on as to whether the purchased materials are reusable or recyclable, or have been recycled already (Sarkis, 2003). It allows organisations to offset environmental and financial risks, rather than inheriting it from suppliers (Zsindisin and Siferd, 2001; Carter, Kale and Grimm, 2000). Green distribution and reverse logistics have important impacts on green SCM (Zhu, Sarkis and Geng, 2005). The operation of green distribution is most closely tied to the customers' requirements and characteristics. European and United States companies have considered reverse logistics as an important aspect for green SCM (Zsidisin and Hendrick, 1998). Government involvement in green SC has shifted emphasis from pollution control to the product life cycle (Lee, 2008). Activities of government involvement range from direct financial and technical support to indirect infrastructure development and encouragement with tax-cut incentives for environmental complexes (Holt, et al., 2001). Using the literature, the researcher has identified green SCM practices into four major groupings. This portion of the research tries to determine the progress of the samples of companies in Chinese construction industry for implementation of green SCM practices. Thus, hypothesis is made as follows:

Hypothesis 2a: Companies in Chinese construction industry are actively adopting and implementing green SCM practices.

Yet, issues facing different sized companies or different industrial sectors may cause green SCM practices to be different in terms of levels of implementation or adoption. Size is the natural logarithmic transformation of the number of full-time employees (Dean and Snell, 1991). Because of extra available resources, large organisations are more likely than smaller ones to have well-developed green SCM practices (Rao, 2002). Large and medium sized companies seem to encounter greater pressures on environmental protection than small ones (Zhu, et al., 2011). Due to different pressures and drivers, companies in different sizes and different industry sectors could make different efforts on green SCM implementations. Small and medium sized companies are generally reactive to the national ecological strategy, but large sized enterprises with stronger environmental commitment are better motivate proactive environmental management (Roy and Therin, 2008). Building material manufacturers as the traditional heavy polluters have struggled to introduce various environment practices. The small plants have shut down in the past decade due to poor environmental images. Companies in different industry sectors have different resources used and different environmental effects by emissions (McMichael, et al., 1998). Given these arguments, the researcher posits hypotheses as follows:

Hypothesis 2b: The level of green SCM implementation is different in small, medium and large sized companies in Chinese construction industry.

Hypothesis 2c: The level of green SCM implementation is different in Chinese construction sector companies and building material sector companies.

Many literatures have investigated the relationships between green SCM practices and performance such as economic performance and environmental performance. However, whether green SCM practices relate to or cause the negative or positive economic performance was still not unclear (Wagner, Schaltegger and Wehrmeyer, 2001). The economic performance is not being reaped in short term performance of sales and profitability (Bowen et al, 2001). Adopting green SCM practices provided informal and formal mechanisms that reduce risk, promote trust, and in turn increase profitability and innovation (Dodgson, 2000). While Alvaredz, Jimenez and Lorente (2001) argued that the green SCM practice had the positive relationship with the economic performance.

Some studies verified the positive relationship between environmental practices and environmental performance. For example, Zhu, Sarkis and Geng (2005) stated that the partnership agreements, interaction of suppliers and customers, and the joint development and research led to the improvement in environmental performance. Geffen and Rothenberg (2000) found that the relations aided the development and adoption of innovative environmental technology. Results in Zhu and Cote (2004) showed that implementation of green SCM led to the improvement in environmental performance. Hanna, Newman and Johnson (2000) found a strong relationship between the involvement of environmental management and meeting environmental goals. To help organisation achieve the environmental targets, a system of environmental management was confirmed as an information management tool and innovative policy of environment (Szwilski, 2000). Thus, the researcher presents the hypothesis as follows:

Hypothesis 2d: Companies in Chinese construction industry with higher levels of adoption of green SCM practices are associated with better environmental performance improvements.

Hypothesis 2e: Companies in Chinese construction industry with higher levels of adoption of green SCM practices are associated with better economic performance improvements.

Chapter 3 Methodology

3.1 Research design and methods

Research on green SCM in Chinese construction industry has been traditionally conducted using empirical data collection and causal observations. Green SCM research generally falls into quantitative (Zhu, et al., 2010; Lee, 2008; Vochon and Klassen, 2006; Rao and Holt, 2005) and qualitative (Zhu and Liu, 2010; Geng, Haight and Zhu, 2007; Zhu and Cote, 2004) methodological groups.

Quantitative research is defined as social research that adopts empirical methods and statements, which describes and explains phenomena by collecting numerical data that are analysed using mathematically based methods (Cohen and Manion, 1980; Creswell, 1994). It is used to quantify behaviours, opinions, attitudes and other defined variables and generalise results from larger sample sizes. Quantitative data collection methods include various forms of surveys, including the paper survey, kiosk survey, mobile survey, online survey, online poll, website interceptor, longitudinal study, telephone interview, face-to-face interview and systematic observation, whose aim is to produce generalizable results and test pre-determined hypotheses. Wyse (2011) states that quantitative data collection methods are more structured than qualitative data collection methods. It is easier to compile the data onto graph or chart because of the numbers that are made available, and it also can be conducted on a large scale as far as value and statistics, however, quantitative research is that numbers change often (Word Press, 2011). Quantitative data is rigorously collected, using appropriate methods and critically analysed in its reliability, but it fails to provide the description of experiences in depth.

In contrast, qualitative research is primarily exploratory study which is used to gain an understanding of a phenomenon or situation or event (Cooper and Schidler, 2008). Questions are often asked during the research process to gain insights into the problem or help developing hypotheses (Wyse, 2011). It is defined as a method of inquiry adopted different academic disciplines, which seeks to gather in-depth understanding of human behaviour and reasons that govern such behaviours (Denzin and Lincoln, 2005). Qualitative research provides added value in identifying and exploring the perception and relationship held by affected organisations and persons. It helps to develop hypotheses or idea and provides insights into problems for quantitative research. Qualitative data collection methods include the individual interview, focus group and observation/ participation. It typically uses small sample size, and its respondents are selected to fulfil a given quota (Wyse, 2011).

This research adopts both inductive and deductive approaches. Inductive approach begins with detailed observations, and theories which are formulated towards as more abstract results of observations at the end of the research (Goddard and Melville, 2004). In the inductive approach, researchers begin by collecting data that is related to their interest topics and search for pattern from theories and observation for those patterns through series of hypotheses (Blackstone, 2015; Bernard, 2011). In inductive approach, there is no theory at the beginning point of the research, and theories could evolve as the results of research. As Blackstone (2015) suggested, researchers move from the specific to the general, or from data to theory. Patterns in experience are observed to generate theory. In contrast, deductive approach is concerned with deducting conclusions that are derived from propositions or premises of the theory. In the deductive approach to research, researchers concern with developing hypotheses based on existing theories that they find compelling and then design a research strategy to test their implications with data (Wilson, 2010; Blackstone, 2015). Researchers move from the more general level to the more specific level.

Inductive and deductive approaches can be rather complementary while these approaches to research seem quite different (Blackstone, 2015). The adoption of deductive approach is generally related to quantitative methods of data collection and analysis, whereas inductive approach is associated with qualitative methods. A quantitative survey was conducted to find out factors affecting (motivating or preventing) Chinese construction company in implementing green SCM practices. In addition, strategies and procedures applied in implementing green SCM practices are also investigated in the survey. To obtain enhanced understandings on the causal relationship among the factors identified in the survey, a detailed analysis on two Chinese company is carried through qualitative case studies, evaluating their incentives and barriers during green SCM implementations. To explore and identify gaps and best practices in green SCM in Chinese construction industry, a benchmarking exercise is conducted to compare the two Chinese case companies with two British case companies. The quantitative survey data were analysed to test hypotheses that were generated based on green SCM theories. Qualitative case studies were used to deeper insights into the causal relationship tested in the survey. The two approaches allow researchers to collect empirical data on the practices on green SCM as well as the specific items of green SCM performance from the targeted organisations.

Questionnaire and case study have been widely used to investigate green SCM (Zhu, et al., 2010; Lee, 2008; Vochon and Klassen, 2006; Zhu, Sarkis and Lai, 2007; Rao and Holt, 2005).

Benchmarking process is used to find the best SCM practices (Banet, et al., 2003; Andersen, et al., 1999). Specifically, the questionnaire is chosen as the research method for the following reasons. Firstly, questionnaire is an efficient method for data collection, as the target respondents are located in different regions in China. Secondly, questionnaire makes it easier to measure the variables in research (Easterby-Smith, Golden-Biddle and Locke, 2008). Thirdly, since most of the target respondents work in large sized enterprises, questionnaire is preferred to minimize the negative influence on their colleagues and working place. Lastly, questionnaire is a good way to protect respondents' privacies if it is completed anonymously.

Furthermore, Finelli (2011) emphasizes that the multiple case study design could increase the validity and reliability of study in research. When combined with multiple case designs, validity is improved although single survey is strong on reliability but weak on validity generally. Finally, the main advantage of benchmarking is that it identifies best practices in key business processes then quantifies the gap between the actual state and expected performance (Richter, 2010). Benchmarking provides organisations in construction industry with both a definition of what green SCM practices improvement and the reason to improve. Since literature review and site observations provide rich data to the research, the adoption of these methods enhances the validity of the research.

Research Methodology	
Quantitative Research: Objective 1)-3) Questionnaire Survey: • Efficient data collection • Measuring variables easily • Minimising negative influence in large sized enterprises • Protecting respondents' privacies	Qualitative Research Case Study: Objective 4) • Increasing validity and reliability Benchmarking: Objective 5) • Quantifying gaps between actual state and expected performance

Figure 3.1 Research Methodology

3.2 Questionnaire design and development

Data were collected primarily through questionnaire survey that will be used to test hypotheses (Objective 1-3). The original questionnaire was written in English, and was translated into Chinese when it was distributed to respondents in China (See Appendix 2). The empirical analysis used in this research contains responses from middle or senior managers in Chinese construction sector, covering both construction companies and building materials companies in China. The purpose of the questionnaire is briefed with targeted respondents.

The questionnaire consists of four sections including a) basic information of participants, b) pressures and drivers affecting green SCM implementation, c) green SCM practices adopted, and d) green SCM performance achieved (see Appendix 1). Section a) includes questions regarding companies' legal and economic status, sizes, environmental management status, and industry sectors. Likert Scale measurement was adopted in the research which is a universal method of collecting data and scaling responses using quantitative data (LaMarca, 2011).

Green SCM drivers/ pressures: based on interviews with industrial experts and a review of literature, ten items scale were developed to measure green SCM pressures/ drivers (as shown in Table 3.1). Items in terms of environmental regulations (Henriques and Sadorisky, 1999), national regulations, environmental policy, green image, liability for disposal hazardous materials (Zhu and Geng, 2001), foreign regulations (Zhu, Sarkis and Geng, 2005), Domestic customers' expectations (Chan and Lau, 2001), and foreign customers' expectations (Christmann and Taylor, 2001) were used as the questionnaire items in the survey. By consulting people from Economic Development Area Bureau of Linyi and several managers of companies in constriction industry, question items such as potential conflicts with national laws and potential conflicts with foreign laws were added by the researcher, as products may fail to conform to either national or foreign environmental laws. Questions were answered using a five-point Likert-type scale, e.g. 1 Strongly Disagree, 2 Disagree, 3 Neither Agree Nor Disagree, 4 Agree, 5 Strongly Agree.

Green SCM practices: based on interviews with industrial experts and a review of literature, sixteen items scale were developed to describe green SCM practices (as shown in Table 3.2). Items on commitment from mid-level management (Carter, Ellram and Kathryn, 1998), commitment from senior level management (Carter, Kale and Grimn, 2000), inter-departmental cooperation, improvement of manufacturing process (Zhu and Sarkis, 2004), cooperation with supplier, environmental requirement, ISO 14000 certification, excess inventory and material (Zsidisn and Hendirck, 1998), Environment friendly transportation, used material and scrap (Zhu, Sarkis and Geng, 2005), infrastructure, assistance from government, and knowledge popularisation (Holt, Anthony and Viney, 2001) were used as the questionnaire items in the survey. By consulting Housing Construction Bureau and Economic Development Area Bureau of Linyi, as well as several managers of companies in constriction industry, question items such as environmental compliance and auditing system, technology utilisation and government coordination were added by the researcher. Interviewees advised that companies need to be compliant with environmental regulations and have a system in place to audit the compliance. The other information they have shared is that companies adopted cleaner technology process to reduce resource and wastes; and coordinated with government for waste treatment and discharge. Questions were answered using the five-point Likert-type scale, e.g. 1 Not Consider, 2 Plans to consider, 3 Current Consider, 4 Initiate Implementing, 5 Successful Implementation. In addition, respondents were asked to share information on the length of period for which green SCM practices has been implemented.

Green SCM performance: based on the interviews with industrial experts and a review of literature, fourteen items scale were developed to examine the degree of green SCM performance (as shown in Table 3.3), including reduction of air emission (Zhu, Sarkis and Geng, 2005), reduction of consumption of hazardous materials, reduction of consumption of energy (Hervani, Helms and Sarkis, 2005), reduction of solid/liquid waste (De Giovanni and Vinzi, 2012), reduction of cost for material procurement (Zhu and Sarkis, 2004), increase of profit margin, improvement of corporate image, increase of market share, increase of sales (Rao and Holt, 2005), increase of investment, increase of efficiency (Zhu, Sarkis and Lai, 2007) and reduction of fee of waste treatment or discharge (Tsai and Hung, 2009). A five-point scale, e.g.1 Not at all, 2 A little bit, 3 To some degree, 4 Relatively Important, and 5 Important, was introduced to answer the questions. To facilitate respondents understanding the different five-point scales adopted, an explanation on the four sections and questions contained in each section were provided at the beginning of the survey (See Appendix 1 the questionnaire in English).

Table 3.1 Categories of drivers/pressures of green supply chain management

Regulation	
Environmental regulations	Henriques and Sadorisky (1999)
National regulations	Zhu and Geng (2001)

Foreign regulations	Zhu, Sarkis and Geng (2005)
Potential conflicts with national laws	Added by the researcher
Potential conflicts with foreign laws	Added by the researcher
Market	
Domestic customers' expectations	Chan and Lau (2001)
Foreign customers' expectations	Christmann and Taylor (2001)
Internal factors	
Green image	Zhu and Geng (2001)
Environmental policy	Zhu and Geng (2001)
Liability for disposal hazardous materials	Zhu and Geng (2001)

Table 3.2 Categories of green supply chain management practices

Internal environmental management	
Commitment from mid-level management	Carter, Ellram and Kathryn (1998)
Commitment from senior level management	Carter, Kale and Grimn (2000)
Inter-departmental cooperation	Zhu and Sarkis (2004)
Improvement of manufacturing process	Zhu and Sarkis (2004)
Environmental compliance and auditing system	Added by the researcher
Green procurement	
Cooperation with supplier	Zsidisin and Hendrick (1998)
Environmental requirement	Zsidisin and Hendrick (1998)
ISO 14000 Certification	Zsidisin and Hendrick (1998)
Green distribution and reverse logistics	
Excess inventory and material	Zsidisin and Hendrick (1998)
Environment friendly transportation	Zhu, Sarkis and Geng (2005)
Used material and scrap	Zhu, Sarkis and Geng (2005)
Technology utilisation	Added by the researcher

Government involvement	
Infrastructure	Holt, Anthony and Viney (2001)
Assistance from government	Holt, Anthony and Viney (2001)
Knowledge popularization	Holt, Anthony and Viney (2001)
Government coordination	Added by the researcher

Table 3.3 Categories of green supply chain management performance

Environmental performance	
Reduction of air emission	Zhu, Sarkis and Geng(2005)
Reduction of consumption of hazardous materials	Hervani, Helms and Sarkis (2005)
Reduction of consumption of energy	Hervani, Helms and Sarkis (2005)
Reduction of solid/liquid waste	De Giovanni and Vinzi (2012)
Economic performance	
Reduction of cost for material procurement	Zhu and Sarkis (2004)
Increase of profit margin	Rao and Holt (2005)
Improvement of corporate image	Rao and Holt (2005)
Increase of market share	Rao and Holt (2005)
Increase of sales	Rao and Holt (2005)
Increase of investment	Zhu, Sarkis and Lai (2007)
Increase of efficiency	Zhu, Sarkis and Lai (2007)
Improvement of productivity	Zhu, Sarkis and Lai (2007)
Improvement of product quality	Zhu, Sarkis and Lai (2007)
Reduction of fee of waste treatment or discharge	Tsai and Hung (2009)

3.2.1 Sampling Design

Randomly designed nationally focused on Email surveys were not used due to the lack of reliable sources of databases for Chinese construction industry. A comprehensive sampling frame of Chinese construction supply chain enterprise does not exist, identifying participation in research is a typical problem. Thus, a convenience sampling was used to elicit a sample of

173 enterprises in Chinese construction industry. The data were collected through a self-administered questionnaire survey. This research relies on the convenience sample extracted from the register list of Housing Construction Bureau and Economic Development Area Bureau of Linyi, as sampling approached adopted by Zhu, Sarkis and Lai (2007) in surveying Chinese automobile industry. Although convenience sampling threatens reliability and generalizability of the survey, using multiple methods can diminish the impact and provide a feasible and appropriate solution.

The decision to seek for the assistance of Housing Construction Bureau and Economic Development Area Bureau is made for the following reasons: 1) All the certificated construction firms must register in Housing Construction Bureau, and many building material companies or their controlled corporations are located in the Economic Development Area of Linyi. 2) The Housing Construction Bureau and Economic Development Area Bureau not only supervise these construction supply chain enterprises but also present the business interests at the local, provincial and national level. 3) The researcher believes these Bureaus are more willing to participate in this research because they are more interested and committed to research and development in the construction sector. 4) Bureaus have great knowledge of Chinese construction sector and can assist the researcher to identify suitable companies in the sector to participate the research. 5) If supported by the Bureaus, the construction companies are more willing to participate in this research.

3.2.2 Questionnaire pre-test

To ensure the Chinese version to be accurate and precise, and convey the correct meaning of the original questionnaire items, the researcher sent the Chinese version to three senior managers for proof reading and scrutiny test, including Jinliang Li- the director of Housing Construction Bureau LanShan Linyi, Sihua Wang- Mayor of Yitang Lanshan Linyi and Jianxiao Yu- Vice President of Mengshan Corporation to test and refine the questionnaire. A few corrections were made to the wording in the questionnaire. The revised questionnaires were then sent to 8 participants for pilot study, including Qingsong Hu- Vice President of Tianyuan Corporation, Xiaolin Bai CTO (Chief Technical Officer) of Tianyuan Corporation, Xiaoting Yue- President of EIFS (external thermal insulation of exterior wall) of Jinsheng Corporation, Xiliang Zou-Vice President of EIFS of Jinsheng Corporation, Jianxiao Yu- Vice President of Mengshan Corporation, Zhaoli Jiang- President of Jinxiang Corporation. Based on their comments and feedback, the questionnaire is improved in terms of language and terminology such as the differences between sino-foreign joint venture and joint venture in Chinese.

3.2.3 Questionnaire distributions

There are four stages in questionnaire distribution. Firstly, the researcher contacted Housing Construction Bureau and Economic Development Area Bureau in Linyi to obtain their permissions and support to the research. The researcher explained to the directors of the Bureaus the research objective and contributions, and obtained their permissions to liaise with Jinliang Li, the director of Housing Construction Bureau and Mr. Sihua Wang, the director of Economic Development Area Bureau about this research. Secondly, the hard copies were distributed to three senior and middle level managers for proof reading and scrutiny test. Thirdly, to narrow research targets and avoid bias, the questionnaires were distributed to construction companies who are traditional polluters and to building material companies who becoming suppliers of construction companies. The target companies are from the list of Housing Construction Bureau and Economic Development Area Bureau. Finally, the middle or higher-level managers in the corporates are invited to complete the questionnaires. 98 construction companies and 75 building material firms participated in the questionnaire survey excluding 8 enterprises that participated in the previous pilot study. Interviews and site visits confirmed participants had a clear understanding and definition of the different scales used for item groupings.

3.3 Case studies

A case study can generate a holistic picture of green SCM implementation. Multiple cases can increase external validity and help guard against observer bias. To gain in depth insight into the causal relationship among factors obtained from the empirical studies (Objective 4), two case studies were conducted. Case one was with a Chinese building material manufacturer, Shandong Jinxiang Aluminium Corporation (SJAC), and the other one was with a Chinese real estate developer, Shandong Jinsheng Corporation (SJSC). To explore and identify best practices and gaps of green SCM practices in construction industry, two further case studies were constructed on two British sustainable buildings (one of them won the award as the most sustainable building in the UK).

Drawing information from the secondary resources, such as building energy reports, sustainability reports, project design rationale and brief. The case studies identified the practices implemented to achieve the sustainability and associated factors influencing the adoption of the practices. With the survey samples, the researcher selected cases based on the following criteria:

- The main business of the company is in construction sector, i.e., either a manufacturer for construction materials, or a construction company.
- The companies adopted and implemented some level of green SCM practices.
- The green SCM implementation altered organisational performance, including both environmental and economic performance, in some obvious way.

The two Chinese cases were conducted with the triangulation from literature review, interviews, and direct observations. Green SCM drivers / pressures, practices and performance identified from literature review are applied and compared with findings from empirical studies. The interviews were conducted with three interviewees who are the top or middle level management in companies. The interview questions were conducted using the green SCM drivers/pressures, practices and performance defined in Chapter 3, including regulation, market, internal factors, internal management, green procurement, green distribution and reverse logistics, government involvement, environmental performance and economic performance. The information collected from interviews is seen by participants as true reflection of the drivers/pressures experienced, practices implemented and performance achieved by businesses.

Observations were made following the interviews. Controlled observations involving event samplings were carried out in the research because they are quick to conduct and the data obtained is easier and quicker to analyse. Behaviour of green SCM was classified into four distinct categories including internal management, green purchasing, green distribution and reverse logistics, and government involvement. These practices encompass process design, packaging, storage, transportation and distribution of raw material and finished products, and recovery and disposal of products and packaging discarded after use. Coding involves numbers of shape coefficient of building, area ratio of window to wall, overall heat transfer coefficient of building envelops, shading coefficient of window, heat loss index of building, efficiency of boiler to describe environmental performance in the construction company. Coding also involves numbers of consumption of materials and energy, air emission, and solid and water waste to evaluate environmental performance in the building material manufacturing company.

The case studies rely on multiple sources of evidence and data collection techniques (Iacono, Brown and Holtham, 2009). To avoid bias from the influence of the researcher's own beliefs and the researcher over participants' behaviours, the documents and archival records related to companies' green SCM were also integrated with the main findings from interviews and observations.

3.4 Benchmarking exercise

To identify gaps and best practices in Chinese and British construction industry and deliver grounded recommendations for future practice (Objective 5), the benchmarking exercise was adopted in this study. The phases of benchmarking process, including planning, analysis and integration were considered in this investigation since 'there is no single benchmarking process that has been universally adopted' (Xie and Breen, 2014, p.463).

Phase 1-planning process: the process to be benchmarked is the Chinese green SCM in construction industry. The key competencies were defined by factor analysis in Chapter 4 and case studies in Chapter 5, including internal environmental management, green procurement, green distribution and reverse logistics, and government involvement (Table 6.6). A comparison under the green SCM framework revealed that similarities exist between Chinese and British construction green SCM (Table 6.7). The green SCM in British construction sector acted as grounds on which it was chosen as the benchmarking partner.

Phase 2-analysis phase: the main purpose of this phase is to explore and identify gaps existing in the green SCM between Chinese construction sector and the British construction sector, the causes of gaps in the initiators (Chinese construction SC) and the enablers of best practices in the benchmarking partners (British construction SC). Under the construction green SCM framework (see Table 6.6), the Chinese construction green SCM practices were compared with the British construction green SCM activities (see Table 6.8) to identify gaps under each key competency.

Phase 3-integration phase: the best practices of green SCM are identified from British companies and authorities according to gaps, causes and enablers obtained in the analysis phase. The Chinese green construction SCM was benchmarked against the identified good practices of British green construction SCM, triangulated by the findings.

Chapter 4 Data Collection and Analysis

4.1 Data collection and sampling characteristics

The participants in this research are middle and senior managers in Chinese construction supply chain companies. Bowen, et al. (2001) found positive relationships exist between middle level managers' perceptions of corporate environmental proactivity and green SCM. Carter, Ellram and Kathryn (1998) also state that the managers at middle management level can facilitate incremental adoption of environmental practice. Hamel and Prahalad (1989) believe the mangers at senior level are the key drivers for successful implementation and adoption of most activities, programs, technologies, and innovations. Johansson (2006) sates the top management support is important to obtain necessary resources for obtaining a go head decision, attracting team members, and providing the funding for project. The researcher administers the survey of construction companies using convenience sampling during the training workshop in Housing Construction Bureau. Additional convenience sample surveys of building material firms are conducted to acquire the information during the workshops in Economic Development Area Bureau. A total of 173 surveys are administered to construction supply chain middle or higher-level managers. At the end, the researcher received 103 unique responses including 51 responses from construction companies accounting for 49.5% of the study samples, and 52 responses from building material firms accounting for 50.5% of the survey samples. The majority of the respondents belonged to Joint Venture corporates (n=77) accounting for 74.8%, 25 respondents belonged to Private sectors (24.3%), 1 respondents belonged to sated owned enterprise (0.9%). 27 respondent companies have less than 100 employees accounting for 26.2%, 37 respondent enterprises have between 100 and 200 employees (35.9%), 16 respondent companies have between 200 and 300 employees (15.5%), 16 respondent enterprises have between 300 and 500 employees (15.5%). 7 respondent corporates have over 500 employees (6.9%) (See Table 4.1).

Table 4.1 shows the distribution of respondent enterprises in terms of ownership, industry sector, and size using employment levels. The respondents are mainly from three ownerships, that is joint venture (74.8%), private sector (24.3%), and sated owned (0.9%). Enterprises sizes ranged from under 100 to over 500 employees, such as small sized those with employees less than 100, medium sized those with employees between 100 and 300, and large sized those with employees over 300（MIIT,2011）, with the majority of the enterprises falling into medium sized enterprise (50.5%) classification of between 101 and 300 employees. Respondents are from two industrial sections: construction sector (49.5%) that is responsible for project management and construction of buildings and building materials sector (50.5%) with main businesses of producing various building materials including electric cable, sheet metal, EIFS (external thermal insulation of exterior wall), aluminium alloy doors and windows, toughened glass, decoration and aluminium alloy etc.

Table 4.1 Distribution of survey respondent enterprises by ownership, size and industry sector

	Total	Percentage
Ownership		
Joint Venture	77	74.8
Private Sector	25	24.3
State Owned	1	0.9
Total	103	100
Size (Employee)		
≤100	27	26.2
100-200	37	35.9
200-300	16	15.5
300-500	16	15.5
≥500	7	6.9
Total	103	100
Small	27	26.2
Medium	52	50.5
Large	24	23.3
Total	103	100
Industry Sector		
Construction	51	49.5
Building Material	52	50.5

Total	103	100

4.2 Factor analysis

When researcher has no prior hypotheses about factors or patterns of measured variables (Finch and West, 1997), exploratory factor analysis (EFA) is usually performed to assess the validity of the measures, to reduce the dimensionality of the original space and to give an interpretation to the new space.

Procedures of EFA are more accurate when each factor is presented by multiple measured variables. Factors of green SCM pressures/drivers, practices and performance were extracted using the maximum likelihood method followed by a varimax rotation. The maximum likelihood method allows researchers to assess the statistical significance of factor loadings, compute correlations among factors and calculate confidence intervals for parameters (Fabrigar, et al., 1999). The varimax rotation method was used to simplify and clarify the data structure. The Kaiser criterion (Kaiser's eigenvalue-greater-than-one rule) was employed with Cattell's scree plot to determine the optimal number of factors to retain in EFA. Both eigenvalue test and scree test suggested the presence of three factors for green SCM pressures/drivers, four factors for green SCM practices, and two factors for green SCM performance that were retained. KMO (Kaiser-Meyer-Olkin) test and Bartlett's test were used to further validate original items groupings.

Based on the KMO test, the three factors of green SCM pressures/drivers explain 68.8% of the inherent variation in the items, the four factors of green SCM practices explain 81.2% of the inherent variation in the items, and the two factors of green SCM performance explain 92.9% of the inherent variation in the items (Table 4.2). The Bartlett's test also indicated the factor analysis was significant useful with the data. Researcher kept the labels of the three factors on green SCM pressures/drivers in terms of regulation, market and internal factors; four factors on green SCM practices, i.e., internal environmental management, green procurement, green distribution and reverse logistics, and government involvement; and two factors on green SCM performance which included environmental performance and economic performance (Tables 4.3-4.5). To further confirm the reliability of these factors on green SCM pressures/ drivers, practices and performance, the Cronbach's alpha value was adopted. All the factors on green SCM pressures/drivers, practices and performance have levels of Cronbach's alpha are higher than 0.70, the threshold value recommended by Nunnally (1978) (Table 4.6), which ensures the construct's validity and consistency.

Table 4.2 KMO Measurement for green SCM pressures/drivers, practices and performance

	Kaiser-Meyer-Olkin measure of Sampling Adequacy
Green SCM pressures/drivers	0.688
Green SCM practices	0.812
Green SCM performance	0.929

Table 4.3 Rotated Factor Matrix on green SCM pressures/ drivers

Survey Items	1	2	3
Regulation			
Environmental regulations	0.829*	-0.038	-0.022
Potential conflicts with national laws	0.777*	-0.053	0.031
Potential conflicts with foreign laws	0.654*	-0.072	-0.079
National regulations	0.669*	0.146	0.227
Foreign regulations	0.724*	0.149	-0.040
Market			
Domestic customers' expectations	0.030	-0.153	0.897*
Foreign customers' expectations	-0.004	-0.063	0.932*
Internal factors			
Green image	0.021	0.929*	-0.084
Environmental policy	0.035	0.904*	-0.077
Liability for disposal hazardous materials	0.008	0.917*	-0.078

Table 4.4 Rotated factor matrix on green SCM practices

Survey items	1	2	3	4
Internal environmental management				
Commitment from senior level management	0.795*	0.091	0.294	-0.032
Commitment from mid-level management	0.820*	0.094	0.238	0.070
Inter-departmental cooperation	0.648*	0.354	0.016	0.132
Environmental compliance and auditing system	0.728*	0.127	-0.047	0.354
Improvement of manufacturing process	0.628*	0.274	0.048	0.177
Green procurement				
Cooperation with supplier	0.182	0.098	-0.029	0.777*
Environmental requirement	0.118	0.144	0.195	0.757*
ISO 14000 Certification	0.084	0.064	0.106	0.801*
Green distribution and reverse logistics				
Environment friendly transportation	0.262	0.218	0.691*	-0.017
Excess inventory and material	-0.078	0.494	0.565*	0.094
Used material and scrap	0.039	0.012	0.726*	0.204
Technology utilization	0.159	0.058	0.763*	0.030
Government involvement				
Government coordination	0.355	0.682*	0.068	-0.063
Infrastructure	0.178	0.772*	0.158	0.184
Assistance from government	0.381	0.767*	0.019	0.093
Knowledge popularization	0.050	0.817*	0.179	0.168

Table 4.5 Rotated factor matrix on green SCM performance

Survey items	1	2
Environmental performance		
Reduction of solid/liquid waste	0.389	0.799*
Reduction of air emission	0.337	0.844*
Reduction of consumption of hazardous materials	0.392	0.852*
Reduction of consumption of energy	0.330	0.744*
Economic performance		
Increase of profit margin	0.740*	0.366
Improvement of corporate image	0.666*	0.495
Increase of investment	0.667*	0.308
Increase of market share	0.803*	0.272
Increase of sales	0.828*	0.332
Increase of efficiency	0.820*	0.387
Improvement of productivity	0.779*	0.389
Improvement of product quality	0.627*	0.518
Reduction of cost for material procurement	0.745*	0.383
Reduction of fee of waste treatment or discharge	0.760*	0.348

Table 4.6 Reliability Statistics for green SCM pressures/drivers, practices, and performance

	Cronbach's alpha	Number of Items
Green SCM pressure/drivers		
Regulation	0.782	5
Market	0.842	2
Internal factors	0.914	3

Green SCM practices		
Internal environmental management	0.834	5
Green procurement	0.738	3
Green distribution and reverse logistics	0.712	4
Government involvement	0.840	4
Green SCM performance		
Environmental performance	0.913	4
Economic performance	0.952	10

4.3 Evaluating hypotheses

The descriptive statistics were used to quantitatively analyse the main features of collected information on green SCM pressures/drivers, practices and performance. Items for each factor on green SCM pressures/drivers, green SCM practices, green SCM performance and other descriptive data in terms of Cronbach's alpha, means, standard deviations and sample size are shown in Tables 4.7-4.9. The mean is used synonymously to refer to one measure of the central tendency (Feller, 1950). The standard deviation is used to quantify the amount of dispersion or variation of a set of data value (Bland and Altman, 1996).

Hypothesis 1a posits that companies in Chinese construction industry are facing significant pressures to adopt green SCM pressures that arise from a variety of sources. In this survey, questions were answered using a five-point Likert-type scale (e.g. 1 Strongly Disagree, 2 Disagree, 3 Neither Agree nor Disagree, 4 Agree, 5 Strongly Agree). As shown in Table 4.7, the means of the factors on green SCM pressures/drivers are 4.2796 for regulation, 4.3689 for market, and 4.2591 for internal factors which are all above 4.00(agree). Among these pressures or drivers, 'Market' pressure is the most important driver with the mean score of 4.3689; 'Regulation' comes second, and 'Internal factors' are the third. Thus, Hypothesis 1a is supported for companies in Chinese construction industry have experienced significant pressures or received strong incentives to implement green SCM practices.

Hypothesis 2a posits that companies in Chinese construction industry are actively adopting and implementing green SCM practices. In this survey, five-point Likert-type scale (e.g. 1 Not Consider, 2 Plans to Consider, 3 Currently Consider, 4 Initiate Implementing, 5 Successful

Implementation) are also utilized in the section about green SCM practices. Table 4.8 presents that the means of the factor of green SCM practices are 4.5465 for internal environmental management, 4.5406 for green procurement, 4.6408 for green distribution and reverse logistics, and 4.5971 for government involvement which are all above 4.00 (initiate implementing) and indicate a good level of green SCM practice adopting and implementation. Therefore, Hypothesis 2a is supported with the results that are in line with those of green SCM pressures/drivers, and prove that the green SCM pressures/drivers have effectively driven green SCM practices in these Chinese enterprises.

In this survey, the five-point Likert-type scale (1. Not at all, 2 A little bit, 3 To some degree, 4 Relatively important, 5 Important) are introduced to the effects on environmental and economic green SCM performance. Both green SCM performance are below 4.00 (relatively important) but above 3.00 (to some degree), with 3.3568 for environmental performance and 3.1951 for economic performance.

Table 4.7 Descriptive statistics for green SCM pressures/ drivers

Survey Items	Mean	Std.Deviation	N
Regulation (α=0.782)	4.2796	0.50824	103
Environmental regulation	4.3592	0.69810	103
Potential conflicts with national laws	4.1650	0.72891	103
Potential conflicts with foreign laws	4.1650	0.74224	103
National regulations	4.4078	0.67790	103
Foreign regulations	4.3010	0.62364	103
			103
Market (α=0.842)	4.3689	0.52841	103
Domestic customers' expectations	4.3592	0.57487	103
Foreign customers' expectations	4.3786	0.56215	103
Internal factors (α=0.914)	4.2591	0.74541	103
Green image	4.2524	0.81311	103

Environmental policy	4.2621	0.81603	103
Liability for disposal hazardous materials	4.2621	0.79164	103

1 Strongly Disagree, 2 Disagree, 3 Neither Agree nor Disagree, 4 Agree, 5 Strongly Agree

Table 4.8 Descriptive statistics for green SCM practices

Survey items	Mean	Std.Dviation	N
Internal environmental management (α=0.834)	4.5165	0.42243	103
Commitment from senior level management	4.5437	0.53827	103
Commitment from mid-level management	4.5922	0.55017	103
Inter-departmental cooperation	4.5146	0.52139	103
Environmental compliance and auditing system	4.4854	0.53986	103
Improvement of manufacturing process	4.4466	0.57272	103
Green procurement (α=0.738)	4.5406	0.41579	103
Cooperation with supplier	4.5825	0.51496	103
Environmental requirement	4.4951	0.50242	103
ISO 14000 Certification	4.5437	0.51974	103
Green distribution and reverse logistics (α=0.712)	4.6408	0.35298	103
Environment friendly transportation	4.6505	0.47915	103
Excess inventory and material	4.6602	0.47596	103
Used material and scrap	4.6408	0.48212	103
Technology utilization	4.6117	0.48976	103
Government involvement (α=0.840)	4.5971	0.40860	103
Government coordination	4.5922	0.49382	103

Infrastructure	4.5825	0.49555	103
Assistance from government	4.5728	0.49709	103
Knowledge popularization	4.6408	0.50204	103

1= Not Consider, 2= Plans to Consider, 3= Currently Consider, 4= Initiate Implementing, 5= Successful Implementation

Table 4.9 Descriptive statistics for green SCM performance

Survey items	Mean	Std.Deviation	N
Environmental performance(α=0.913)	3.3568	1.02338	103
Reduction of solid/liquid waste	3.2330	1.15643	103
Reduction of air emission	3.2330	1.14792	103
Reduction of consumption of hazardous materials	3.3107	1.15495	103
Reduction of consumption of energy	3.6505	1.13508	103
Economic performance (α=0.952)	3.1951	0.97713	103
Increase of profit margin	2.9806	1.12877	103
Improvement of corporate image	3.4563	1.20275	103
Increase of investment	3.3883	1.11349	103
Increase of market share	3.2136	1.12590	103
Increase of sales	3.1942	1.23716	103
Increase of efficiency	3.1845	1.21064	103
Improvement of productivity	3.2524	1.08210	103
Improvement of product quality	3.3592	1.11895	103
Reduction of cost for material procurement	2.9223	1.25783	103
Reduction of fee of waste treatment or discharge	3.0000	1.20457	103

1= Not at all, 2= A little bit, 3 =To some degree, 4= Relatively Important, 5= Important

Analysis of variance (ANOVA) and t-tests were introduced to assess the variations in green SCM pressures/drivers, practices and performance in different sized enterprises and different industry sectors. The samples of the enterprises were categorized into three groups in term of the establishment of the employees and two groups in terms of the establishment of industry sectors, such as small sized those with employees less than 100, medium sized those with employees between 100 and 300, large sized those with employees more than 300, construction enterprises and building materials enterprises (Table 4.1). A one-way ANOVA was used to evaluate if the statistically significant differences exist in green SCM pressures, practices and performance in the samples of enterprises. And the two-tailed independent samples t-tests were utilized to compare the differences between different size and industry sector. The composite factors were compared before the evaluation of the specific items in order to obtain the overall results.

In the EFA, the items of green SCM pressures were grouped into three dimensions such as regulation, market and internal factors; the green SCM practices were classified into four categories in terms of internal environmental management, green procurement, Green distribution and reverse logistics, and government involvement; and green SCM performance is originated two groups including environmental performance and economic performance. Tables 4.10-4.15 separately provide each categories and specific items within the questionnaire. The composite factors and items for each factor of green SCM pressures/drivers, practices and performance together with means and standard deviations were also presented in these tables.

The results of ANOVA for green SCM pressures in Table 4.10 indicate that as a composite factor, only *'regulation'* has statistically significant differences (p-value=0.008**) among three firm sizes. The ANOVA results for green SCM practices in Table 4.11 do not show any statistically significant difference across the enterprises size. The ANOVA results for green SCM performance in Table 4.12 present that the composite factor of *'economic performance'* has statistically significant differences (p-value=0.004**) among the firm sizes. In specific, the results of t-test in Table 4.10 show that the medium sized enterprises have the highest *'regulation'* pressure (mean=4.40), significantly stronger than small sized enterprises (p-value=0.002**). And large sized enterprises haves slightly stronger *'regulation'* pressures than small sized enterprises (p-value=0.075+). In Table 4.12, the t-test results present the medium sized enterprise have the highest positive *'economic performance'* (mean=3.41), significantly higher than small sized enterprises (p-value=0.001**), and large sized enterprises also have significantly higher positive 'economic performance' than small sized firms (p-value= 0.020*).

Hypothesis 1b posits that the level of green SCM pressures/drivers is different in small, medium and large sized companies in Chinese construction industry. In Table 4.10, ANOVA results show that the composite factor of *'regulation'* has the statistically significant differences (p-value=0.008**) across three firm sizes, in specific, the item of *'environmental regulation'* has the statistically significant difference (p-value=0.008**), the items of *'national (domestic) regulation'* also has the statistically significant differences (p-value=0.003**). As a composite factor, *'market'* does not have any statistically significant differences among small, medium and large sized enterprises, however, the item of *'foreign customers'* expectations' pressure has slightly differences (p-value=0.051+) across three sized enterprises. The composite factor- *'internal factors'* has no statistically significant differences among three different sizes of company. Furthermore, the results of t-test show that the medium sized enterprises have the highest *'regulation'* pressures (mean=4.40), significantly stronger than small sized enterprises (p-value=0.002**). And large sized enterprises haves slightly stronger *'regulation'* pressures than small sized enterprises (p-value=0.075+). The medium sized enterprises have the highest *'environmental regulation'* pressures (mean=4.46), significantly stronger than small sized (p-value=0.004**) and large sized (p-value=0.036*) companies. Medium sized enterprises have slightly stronger *'breach of national laws'* than small sized enterprises (p-value=0.061+). The small sized enterprises have significantly weaker *'national (domestic) regulations'* than medium sized (p-value=0.002**) and large sized (p-value=0.008**) enterprises. The small sized companies have slightly stronger *'market'* pressures than medium sized ones (p-value=0.071+). The small sized enterprises have significantly stronger *'foreign customers' expectations'* pressures than medium sized enterprises (p-value=0.025*). Thus, Hypothesis 1b is not supported in this study.

Hypothesis 2b posits that the level of green SCM implementation is different in small, medium and large sized companies in Chinese construction industry. In Table 4.11, the results of ANOVA present that the composite factor 'green procurement' has a slightly significant differences (p-value=0.072+) across small, medium and large sized enterprises. The results of variance analysis also indicate there are not any statistically significant differences among three different sizes companies for the composite factors of green SCM practices including *'internal environmental management'*, *'Green distribution and reverse logistics'*, and *'government involvement'*. The item of *'environmental requirement*' has a statistically significant difference (p-value=0.005**) among three sizes enterprises. Furthermore, t-test results show that the medium sized enterprises have the highest *'green procurement'* practices (mean=4.61), significantly stronger than large sized firms (p-value=0.016*). The item of *'cooperation with supplier'* has a slightly difference between medium sized and large sized enterprises, and the medium sized enterprises have the highest mean value of *'cooperation with supplier'* (mean=4.67). The small sized enterprises have the highest *'environmental requirement'* practices (mean=4.59), significantly stronger than medium sized enterprises (p-value=0.005**). And there is a statistically significant difference between medium and large sized companies in the green SCM practices item of *'environmental requirement'* (p-value=0.002**). There is also a slightly difference between small and large sized enterprises in the item of 'government coordination' (p-value=0.079+). Therefore, Hypothesis 2b is not supported in this research.

In Table 4.12, ANOVA results predicate that there is not any statistically significant difference in the composite green SCM performance factor of *'environmental performance'* across three different sizes companies. In contrast, the composite factor of *'economic performance'* has a statistically significant difference among small, medium and large sized enterprises (p-value=0.004**). And the statistically significant differences across three different sized enterprises also exist in the items of *'improvement of corporate image'* (p-value=0.015*), *'increase of investment'* (p-value=0.000***), *'increase of market share'* (p-value=0.003**), *'increase of sales'* (p-value=0.009**), *'increase of efficiency'* (p-value=0.009**), *'improvement of productivity'*(p-value=0.010*), and *'reduction of fee of waste treatment or discharge'* (p-value=0.021*). Furthermore, the results of t-test support that there is a slightly significant difference between small and medium sized enterprises in the item of *'reduction of consumption of energy'* (p-value=0.050+). The small sized enterprises have the lowest *'economic performance'* (mean=2.68), significantly lower than medium sized enterprises (p-value=0.001**) and large sized corporates (p-value=0.020*). The medium sized corporates have the highest *'increase of profit margin'* (mean=3.15), significantly stronger than small size enterprises (p-value= 0.026*). The small size corporates have the lowest *'improvement of corporate image'* (mean=2.89), significantly lower than medium sized enterprises (p-value=0.004**) and large sized enterprises (p-value=0.026*). The small sized enterprises have the lowest *'increase of investment'* (mean=2.67), significantly lower than medium sized (p-value=0.000***) and large sized (0.001**) corporates. The small sized companies have the lowest *'increase of market share'* (mean=2.59), significantly lower than medium sized (p-value=0.001**) and large sized (0.004**) enterprises. Small sized corporates have the lowest *'increase of sales'* (mean=2.59), significantly lower than medium sized enterprises (p-value=0.001**) and slightly different with large sized enterprises (p-value=0.064+). Small sized enterprises have the lowest *'increase of efficiency'* (mean=2.59), significantly lower than medium size corporates (p-value=0.001**) and slightly different with large sized enterprises (p-value=0.051+). Small sized companies have the lowest *'improvement of productivity'* (mean=2.89) and significantly lower than medium sized enterprises (p-value=0.034*). Small sized enterprises have lowest *'improvement of product quality'* (mean=2.81), significantly lower than medium sized (p-value=0.006**) and large sized (p-value=0.010*) companies. Small sized enterprises also have lowest *'reduction of fee of waste treatment or discharge'* (mean=2.48), significantly lower than medium sized companies (p-value=0.004) and slightly different with large sized companies (p-value=0.098+).

Hypothesis 1c posits that the level of green SCM pressures/drivers is different in Chinese construction sector companies and building material sector companies. In Table 4.13, ANOVA and t-test results for green SCM pressures/drivers indicate that *'regulation'* and *'market'* are composite factors for both construction and building material sectors. While *'internal factors'* influence construction sector slightly different from building material sector (p-value=0.059+). The construction sector enterprises have significantly stronger *'national (domestic) regulations'* pressure than building material sector companies (p-value=0.016*). The construction sector enterprises have significantly stronger *'green image'* pressures than building material sector companies (p-value=0.048*). And the construction sector enterprises have significantly stronger *'environmental policy'* pressures than building material sector companies (p-value=0.036*). Thus, Hypothesis 1c is not supported in this study.

Hypothesis 2c posits that the level of green SCM implementation is different in Chinese construction sector companies and building material sector companies. ANOVA and t-test results for green SCM practices in Table 4.14 show only the implementation of 'Green procurement' has statistically significant difference between two sectors. The implementation of *'green procurement'* in construction sector enterprises is significantly stronger than one in the building material sector companies (p-value=0.030*). The construction sector enterprises have significantly stronger *'environmental requirement'* practices than building material sector companies (p-value=0.001**). Other composite green SCM practices including *'internal environmental management'*, *'Green distribution and reverse logistics'*, and *'government involvement'* are adopted or implemented at similar levels by the two industry sectors. Therefore, Hypothesis 2c is not supported in this study.

Finally, ANOVA and t-tests results for green SCM performance in Table 4.15 present that both the composite factors, such as *'environmental performance'* and *'economic performance'*, do not have any statistically significant differences between two Chinese construction industry sectors.

Table 4.10 Comparison of green SCM pressures/ drivers in Chinese construction enterprises with different sizes

Items		S		M		L			ANOVA	T test		
		n=27		n=52		n=24			p-value	p-value		
		Mean	S.D	Mean	S.D	Mean	S.D			S and M	S and L	M and L
Regulation		4.03	0.568	4.40	0.446	4.30	0.483		0.008**	0.002**	0.075+	0.379
Environmental regulation		4.07	0.874	4.46	0.574	4.25	0.608		0.008**	0.004**	0.414	0.036*
Potential conflicts with national laws		3.93	0.829	4.25	0.653	4.25	0.737		0.140	0.061+	0.149	1.000
Potential conflicts with foreign laws		3.96	0.854	4.23	0.744	4.17	0.565		0.222	0.103	0.326	0.551
National regulations		4.04	0.649	4.54	0.641	4.54	0.658		0.003**	0.002**	0.008**	0.984
Foreign regulations		4.15	0.456	4.38	0.690	4.29	0.624		0.280	0.113	0.349	0.576
Market		4.50	0.439	4.27	0.573	4.44	0.496		0.141	0.071+	0.635	0.219
Domestic customers’ expectations		4.44	0.506	4.29	0.637	4.42	0.504		0.449	0.273	0.845	0.388
Foreign customers’ expectations		4.56	0.506	4.25	0.590	4.46	0.509		0.051+	0.025*	0.498	0.140
Internal factors		4.20	0.770	4.22	0.808	4.42	0.558		0.496	0.912	0.254	0.280
Green image		4.15	0.864	4.21	0.871	4.46	0.588		0.351	0.759	0.145	0.212
Environmental policy		4.07	0.917	4.31	0.853	4.38	0.576		0.361	0.264	0.173	0.727

Liability for disposal hazardous materials		4.37	0.742	4.13	0.886	4.42	0.584		0.253	0.240	0.807	0.160

+ p-value <0.10, * p-value <0.05, ** p-value <0.01, *** p-value <0.001

S=Small sized, M=Medium sized, L=Large sized

1=Strongly Disagree, 2= Disagree, 3 =Neither Agree nor Disagree, 4= Agree, 5= Strongly Agree

Table 4.11 Comparison of green SCM practices in Chinese construction enterprises with different sizes

Items		S		M		L			ANOVA	T test		
		n=27		n=52		n=24			p-value	p-value		
		Mean	S.D	Mean	S.D	Mean	S.D			S and M	S and L	M and L
Internal environmental management		4.53	0.454	4.53	0.365	4.48	0.510		0.860	0.946	0.668	0.614
Commitment from senior level management		4.63	0.492	4.52	0.505	4.50	0.659		0.625	0.355	0.427	0.889
Commitment from mid-level management		4.52	0.580	4.63	0.525	4.58	0.584		0.675	0.371	0.693	0.704
Inter-departmental cooperation		4.56	0.506	4.50	0.542	4.50	0.511		0.895	0.660	0.699	1.000
Environmental compliance and auditing system		4.44	0.577	4.54	0.503	4.41	0.584		0.597	0.456	0.865	0.354
Improvement of manufacturing process		4.52	0.580	4.44	0.539	4.38	0.647		0.673	0.563	0.407	0.637
Green procurement		4.56	0.472	4.61	0.378	4.38	0.398		0.072+	0.586	0.150	0.016*
Cooperation with supplier		4.52	0.580	4.67	0.474	4.46	0.509		0.182	0.207	0.697	0.077+

Environmental requirement		4.59	0.501	4.58	0.499	4.21	0.415		0.005**	0.895	0.005**	0.002**
ISO 14000 Certification		4.56	0.577	4.58	0.499	4.46	0.509		0.650	0.865	0.529	0.342
Green distribution and reverse logistics		4.72	0.335	4.61	0.368	4.63	0.338		0.372	0.174	0.308	0.829
Environment friendly transportation		4.78	0.424	4.62	0.491	4.58	0.504		0.267	0.149	0.141	0.794
Excess inventory and material		4.74	0.447	4.60	0.495	4.71	0.464		0.379	0.207	0.801	0.353
Used material and scrap		4.74	0.447	4.58	0.499	4.67	0.482		0.346	0.156	0.571	0.464
Technology utilization		4.63	0.492	4.63	0.486	4.54	0.509		0.730	0.966	0.534	0.448
Government involvement		4.70	0.399	4.56	0.389	4.55	0.454		0.289	0.133	0.210	0.918
Government coordination		4.74	0.447	4.56	0.502	4.50	0.511		0.172	0.115	0.079+	0.644
Infrastructure		4.70	0.465	4.52	0.505	4.58	0.504		0.295	0.118	0.379	0.608
Assistance from government		4.63	0.492	4.56	0.502	4.54	0.509		0.784	0.545	0.534	0.898
Knowledge popularization		4.74	0.447	4.62	0.491	4.58	0.584		0.473	0.271	0.282	0.804

+ p-value <0.10, * p-value <0.05, ** p-value <0.01, *** p-value <0.001

S=Small sized, M=Medium sized, L=Large sized

1= Not Consider, 2= Plans to Consider, 3= Currently Consider, 4= Initiate Implementing, 5= Successful Implementation

Table 4.12 Comparison of green SCM performance in Chinese construction enterprises with different sizes

Items		S		M		L			ANOVA	T test		
		n=27		n=52		n=24			p-value	p-value		
		Mean	S.D	Mean	S.D	Mean	S.D			S and M	S and L	M and L
Environmental performance		3.14	0.918	3.47	1.060	3.36	1.058		0.406	0.177	0.419	0.698
Reduction of solid/liquid waste		3.04	1.018	3.29	1.160	3.33	1.308		0.589	0.345	0.368	0.881
Reduction of air emission		3.11	1.086	3.33	1.200	3.17	1.129		0.697	0.436	0.859	0.583
Reduction of consumption of hazardous materials		3.11	1.050	3.42	1.194	3.29	1.197		0.525	0.255	0.569	0.657
Reduction of consumption of energy		3.30	0.993	3.83	1.184	3.67	1.129		0.143	0.050+	0.218	0.580
Economic performance		2.68	0.789	3.41	0.941	3.30	1.065		0.004**	0.001**	0.020*	0.653
Increase of profit margin		2.59	0.931	3.15	1.092	3.04	1.334		0.106	0.026*	0.166	0.699
Improvement of corporate image		2.89	0.974	3.67	1.184	3.63	1.313		0.015*	0.004**	0.026*	0.874
Increase of investment		2.67	0.832	3.63	1.030	3.67	1.239		0.000***	0.000***	0.001**	0.906
Increase of market share		2.59	0.888	3.40	1.071	3.50	1.251		0.003**	0.001**	0.004**	0.731
Increase of sales		2.59	1.083	3.48	1.146	3.25	1.391		0.009**	0.001**	0.064+	0.449
Increase of efficiency		2.59	0.971	3.46	1.163	3.25	1.359		0.009**	0.001**	0.051+	0.487

Improvement of productivity		2.89	1.013	3.42	1.054	3.29	1.160		0.112	0.034*	0.192	0.626
Improvement of product quality		2.81	1.001	3.50	1.019	3.67	1.274		0.010*	0.006**	0.010*	0.543
Reduction of cost for material procurement		2.67	1.038	3.13	1.268	2.75	1.422		0.219	0.103	0.811	0.241
Reduction of fee of waste treatment or discharge		2.48	0.802	3.27	1.239	3.00	1.351		0.021*	0.004**	0.098+	0.395

+ p-value <0.10, * p-value <0.05, ** p-value <0.01, *** p-value <0.001

S=Small sized, M=Medium sized, L=Large sized

1= Not at all, 2= A little bit, 3 =To some degree, 4= Relatively Important, 5= Important

Table 4.13 Comparison of green SCM pressures/drivers in different industry sectors

Items		Cons		Buil			ANOVA	T test
		n=51		n=52			p-value	p-value
		Mean	S.D	Mean	S.D			
Regulation		4.34	0.443	4.22	0.564		0.256	0.256
Environmental regulation		4.43	0.608	4.29	0.776		0.301	0.301
Potential conflicts with national laws		4.24	0.681	4.10	0.774		0.335	0.335
Potential conflicts with foreign laws		4.08	0.688	4.25	0.789		0.243	0.243
National regulations		4.57	0.575	4.25	0.738		0.016*	0.016*
Foreign regulations		4.37	0.631	4.23	0.614		0.251	0.251

Market		4.32	0.607	4.41	0.440		0.390	0.390
Domestic customers' expectations		4.33	0.622	4.38	0.530		0.653	0.653
Foreign customers' expectations		4.31	0.616	4.44	0.502		0.248	0.248
Internal factors		4.40	0.600	4.12	0.848		0.059+	0.059+
Green image		4.41	0.638	4.10	0.934		0.048*	0.048*
Environmental policy		4.43	0.640	4.10	0.934		0.036*	0.036*
Liability for disposal hazardous materials		4.35	0.627	4.17	0.923		0.251	0.251

+ p-value <0.10, * p-value <0.05, ** p-value <0.01, *** p-value <0.001

Cons=Construction enterprises, Buil=Building material enterprises

1=Strongly Disagree, 2= Disagree, 3 =Neither Agree nor Disagree, 4= Agree, 5= Strongly Agree

Table 4.14 Comparison of green SCM practices in different industry sectors

Items		Cons		Buil			ANOVA	T test
		n=51		n=52			p-value	p-value
		Mean	S.D	Mean	S.D			
Internal environmental management		4.47	0.460	4.56	0.383		0.320	0.320
Commitment from senior level management		4.53	0.542	4.56	0.539		0.791	0.791

Commitment from mid-level management		4.59	0.606	4.60	0.495		0.942	0.942
Inter-departmental cooperation		4.45	0.541	4.58	0.499		0.222	0.222
Environmental compliance and auditing system		4.45	0.541	4.52	0.542		0.524	0.524
Improvement of manufacturing process		4.35	0.594	4.54	0.541		0.100	0.100
Green procurement		4.45	0.394	4.63	0.421		0.030*	0.030*
Cooperation with supplier		4.55	0.503	4.62	0.530		0.516	0.516
Environmental requirement		4.33	0.476	4.65	0.480		0.001**	0.001**
ISO 14000 Certification		4.47	0.504	4.62	0.530		0.158	0.158
Green distribution and reverse logistics		4.62	0.340	4.66	0.367		0.513	0.513
Environment friendly transportation		4.61	0.493	4.69	0.466		0.374	0.374
Excess inventory and material		4.59	0.497	4.73	0.448		0.129	0.129
Used material and scrap		4.63	0.488	4.65	0.480		0.783	0.783
Technology utilization		4.65	0.483	4.58	0.499		0.470	0.470
Government involvement		4.57	0.425	4.62	0.394		0.565	0.565

Government coordination		4.63	0.488	4.56	0.502		0.476	0.476
Infrastructure		4.51	0.505	4.65	0.480		0.141	0.141
Assistance from government		4.53	0.504	4.62	0.491		0.383	0.383
Knowledge popularization		4.63	0.488	4.65	0.520		0.791	0.791

+ p-value <0.10, * p-value <0.05, ** p-value <0.01, *** p-value <0.001

Cons=Construction enterprises, Buil=Building material enterprises

1= Not Consider, 2= Plans to Consider, 3= Currently Consider, 4= Initiate Implementing, 5= Successful Implementation

Table 4.15 Comparison of green SCM performance in different industry sectors

Items		Cons		Buil			ANOVA	T test
		n=51		n=52			p-value	p-value
		Mean	S. D	Mean	S. D			
Environmental performance		3.37	1.023	3.35	1.034		0.916	0.916
Reduction of solid/liquid waste		3.27	1.201	3.19	1.121		0.720	0.720
Reduction of air emission		3.20	1.132	3.30	1.173		0.748	0.748
Reduction of consumption of hazardous materials		3.33	1.143	3.29	1.177		0.845	0.845
Reduction of consumption of energy		3.67	1.178	3.63	1.103		0.887	0.887

Economic performance		3.29	0.956	3.10	0.998		0.331	0.331
Increase of profit margin		3.02	1.157	2.94	1.110		0.730	0.730
Improvement of corporate image		3.61	1.234	3.31	1.164		0.207	0.207
Increase of investment		3.51	1.155	3.27	1.069		0.275	0.275
Increase of market share		3.35	1.110	3.08	1.135		0.215	0.215
Increase of sales		3.25	1.246	3.13	1.237		0.624	0.624
Increase of efficiency		3.29	1.205	3.08	1.218		0.365	0.365
Improvement of productivity		3.33	1.071	3.17	1.098		0.455	0.455
Improvement of product quality		3.53	1.138	3.19	1.085		0.127	0.127
Reduction of cost for material procurement		2.88	1.321	2.96	1.204		0.751	0.751
Reduction of fee of waste treatment or discharge		3.12	1.211	2.88	1.199		0.329	0.329

+ p-value <0.10, * p-value <0.05, ** p-value <0.01, *** p-value <0.001

Cons=Construction enterprises, Buil=Building material enterprises

1= Not at all, 2= A little bit, 3 =To some degree, 4= Relatively Important, 5= Important

Correlation and regression analysis were used to identify relationships among green SCM pressures/ drivers, practices and performance since they are related in the sense that both deal with relationships among variables. The correlations between green SCM pressures/drivers and green SCM practices and in turn between green SCM practices and green SCM performance were examined using Pearson correlation coefficients to 'determine the empirical relationship between the two variables' (Babbie, 2009). Since correlation does not imply causation, the regression analysis is used to examine the causal relationships (Armstrong, 2012) between green SCM pressures/drivers, practices and performance in the samples of Chinese enterprises in construction industry.

Items for each factor on green SCM pressures/drivers, green SCM practices, and green SCM performance and other regression results in terms of significant p-value, variance inflation factor (VIF), and adjusted R square are shown in Tables 4.18, 4.19.

In the relevant regression models, each factor of the pressures/drivers, practices and performance of green SCM are average from the underlying items of the measurement to form a single indicator factor. Moreover, the use of summary factors allows us to examine the relationships based on small size (n=103) and can reduce the model complexity. Thus, the summary factors are consequently used for the regression analysis.

The firm size and industry section may influence the extent of the green SCM practices; therefore, both firm size and industry section are included as the control variables in the regression analysis. In the four regression models, the three factors of green SCM pressures/drivers, i.e. regulation, market, and internal factors are defined as the independent variables to assess their influences on the four factors of green SCM practices including internal environmental management, green procurement, green distribution and reverse logistics, and government involvement. Similarity, the four factors of green SCM practices are treated as the independent variables to examine their influences on the green SCM performance including environmental performance and economic performance in the two regression models.

The VIF was introduced to test the potential existence of multi-collinearity in the regression analysis. The calculated VIF values in all regression models are less than 1.70 (Tables 4.18-4.19). According to Mason and Perreault (1991), the multi-collinearity exists in all regression models as the maximum level of VIF value is below 10.00. The variance adjusted R squared, can provide information to interpret the strengths of the collective impacts of the independent variables on the dependent variables (Zhu, Sarkis and Lai, 2007) in the regression models. For example, the variance explains the percentage of change in green SCM practices (dependent variables) can be collectively predicted by green SCM pressures (independent variables) in regression models (See Table 4.18), and the percentage of change in green SCM performance (dependent variables) can be collectively predicted by green SCM practices (independent variables) in regression models (See Table 4.19).

Hypothesis 1d, 1e, 1f and 1g posit companies with higher levels of green SCM pressures/drivers are associated with higher levels of levels of internal environmental management, green procurement, green distribution and reverse logistics, and government involvement practices in Chinese construction industry. In this study, inter-correlations between green SCM pressures/drivers and green SCM practices are presented in Table 4.16. The results show that a significant relationship (Pearson Correlation value is 0.409**) exists between *'internal environmental management'* (PraC-01) and *'regulation'* (PerS-01); that a strong relationship (Pearson Correlation value is 0.380**) exists between *'government involvement'* (PraC-04) and *'regulation'* (PerS-01), and there is a clear relationship (Person Correlation value is 0.292**) between *'government involvement'* (PraC-04) and *'market'* (PerS-02). In contrast, *'internal environmental managemen*t' does not have significant correlations with *'market'* and *'internal factors'*. *'Green procurement'* does not have significant correlations with all factors of green SCM pressures/drivers in terms of regulation, market and internal factors. *'Green distribution and reverse logistics'* does not have significant correlation with the factors of green SCM pressures/drivers such as regulation, market and internal factors. And *'government involvement'* does not have significant correlation with *'internal factors'*.

The correlation analysis results show that a significant relationship exists between *'internal environmental management' and 'regulation'*, a strong relationship exists between *'government involvement'* and *'regulation'*, and there is a clear relationship between *'government involvement'* and *'market'*. In contrast, *'internal environmental management'* does not have significant correlations with *'market'* and *'internal factors'*. *'Green procurement'* does not have significant correlations with all factors of green SCM pressure in terms of regulation, market and internal factors. *'Green distribution and reverse logistics'* does not have significant correlation with the factor of green SCM pressure such as regulation, market and internal factors. And *'government involvement'* does not have significant correlation with *'internal factors'*.

In Table 4.18, it shows that there is a clear and positive relationship between *'regulation'* and green SCM practices such as *'regulation'* has significantly positive influences on *'internal environmental management'* (β=0.422***), *'green procurement'*(β=0.214*) and *'government involvement'* (β=0.402***), and slightly positive influence on *'green distribution and reverse logistics'* (β=0.184+). *'Market'* is likely to have no significant influences on most of green SCM practice in terms of internal management, green procurement and green distribution and reverse logistics, however, has a significantly positive influence on *'government involvement'* (β=0.281**). The *'internal factors'* have slightly positive influences on *'internal environmental management'* (β=0.174+) and *'green distribution and reverse logistics'* (β =0.170+) but seem to not have any significant impacts on *'green procurement'* and *'government involvement'*. In addition, as the control variable, the firm size has a significantly negative impact on *'government involvement'* (β =-0.235*). The possible explanation is that Chinese enterprises have experienced strong pressures from the relevant environmental regulations, but they may face the similar and every early pressure or drivers from market and the internal motivations. And the government has reflected the pressure/ drivers of market to adopt green SCM practices, but the enterprises may react at the different peace to adopt practices of green SCM when facing to the market pressure and internal motivation. Although the government actively involves the adoption of green SCM practices, the practices of green SCM in enterprises may be more significant as the green SCM pressure/drivers become more mature and adoption since most of the enterprises in Chinese construction industry are at the early stage of green SCM practices. The variance explained in each regression models between green SCM practices and pressures are: 18.9% of the variance in *'internal environmental management'*, 5.7% of the variance in *'green procurement'*, 4.5% of the variance in *'green distribution and reverse logistics'* and 23.1% of the variance in *'government involvement'*. It indicates that 18.9% of the change on *'internal environmental management'*, 5.7% of the change on *'green procurement'*, 4.5% of the change on *'green distribution and reverse logistics'* and 23.1% of the change on *'government involvement'* can be accounted for the three factors of green SCM pressures/drivers in the samples of Chinese construction industry. Thus, Hypothesis 1d, 1e, 1f, and 1g are supported.

Hypothesis 2d, 2e posit that companies in Chinese construction industry having higher levels of adoption of green SCM practices have better green SCM performance improvements. In this study, correlations between green SCM practice and green SCM performance are summarized in Table 4.17. The results reveal that there is a significant relationship (Pearson Correlation value is 0.263**) between *'environmental performance'* (PerF-01) and *'green procurement'* (PraC-02); that there is a strong relationship (Pearson Correlation value is 0.257**) between *'environmental performance'* (PerF-01) and *'green distribution and reverse logistics'* (PraC-03), and a clear relationship (Pearson Correlation value is 0.198*) exists between *'environmental performance'* (PerF-01) and *'government involvement'* (PraC-04). The results also identify a significant relationship (Pearson Correlation value is 0.206*) between *'economic performance'* (PerF-02) and *'internal environmental management'* (PraC-01), a strong relationship (Pearson Correlation value is 0.233*) between *'economic performance'* (PerF-02) and *'green procurement'* (Prac-02), and a clear relationship (Pearson Correlation value is 0.212*) between *'economic performance'* (PerF-02) and *'government involvement'* (PerC-04). In contrast, *'environmental performance'* does not have significant correlation with *'internal environmental management'*, and the *'economic performance'* does not have significant correlation with *'green distribution and reverse logistics'*.

In addition, the relationship between green SCM practices and green SCM performance in the sample of Chinese construction industry is portrayed in Table 4.17 with the results of bivariate correlation using Pearson correlation coefficients. The result shows that a significant relationship between *'environmental performance'* and *'green procurement'*, a strong relationship between *'environmental performance'* and *'green distribution and reverse logistics'*, and a clear relationship between *'environmental performance'* and *'government involvement'*. The result also presents that a significant relationship between *'economic performance'* and *'internal environmental management'*, a strong relationship between *'economic performance'* and *'green procurement'*, and a clear relationship between *'economic performance'* and *'government involvement'*. In contrast, *'environmental performance'* does not have significant correlation with *'internal environmental management'*. And the *'economic performance'* does not have significant correlation with '*green distribution and reverse logistics'*.

The results in Table 4.19 indicate that both environmental performance and economic performance seem to not have any significant relationships with each factor of green SCM practices such as internal management, green procurement, green distribution and reverse logistics, and government involvement. , '*green procurement'* has slightly positive impacts on both *'environmental performance'* (β =0.208+) and *'economic performance'* (β =0.198+). *'Green distribution and reverse logistics'* has a slightly positive influence on *'environmental performance'* (β =0.184+). In addition, as the control variable, firm size has a significantly positive impact on *'economic performance'* (β =0.306**). The possible explanation is that the larger size enterprise may have more competitive advantages in the market. And since most of the enterprises just initiate implementing green SCM practices, the green SCM performance may be more obvious as the adoption of green SCM practices become more matured and widespread in Chinese construction industry. The variance explained in each regression models between green SCM performance and practices are: 7.7% of the variance in *'environmental performance'*, 11.2% of the variance in *'economic performance'*. It predicts that 7.7% of the change on *'environmental performance'* and 11.2% change on *'economic performance'* can be accounted for by the four green SCM practices. Thus, Hypothesis 2d, 2e that posit companies in Chinese construction industry having higher levels of adoption of green SCM practices have better environmental and economic performance improvements are supported.

Table 4.16 Correlation between green SCM pressures/drivers and practices

	PreS-01	PreS-02	PreS-03	PraC-01	PraC-02	PraC-03	PraC-04
Pressures/drivers							
PreS-01	1	0.54	0.048	0.409**	0.181	0.172	0.380**
PreS-02	0.054	1	-0.191	0.126	0.028	0.146	0.292**
PreS-03	0.48	-0.191	1	0.140	0.068	0.130	0.045
Practices							
PraC-01	0.409**	0.126	0.140	1	0.353**	0.343**	0.519**
PraC-02	0.181	0.028	0.068	0.353**	1	0.250*	0.295**
PraC-03	0.172	0.146	0.130	0.343**	0.250*	1	0.401**
PraC-04	0.380**	0.292**	0.045	0.519**	0.295**	0.401**	1

**Correlation is significant at the 0.01level (two-tailed)
*Correlation is significant at the 0.05 level (two-tailed)
PerS-01: Regulation, PerS-02: Market, PreS-03: Internal factors, Pra-C01: Internal environmental management, PraC-02: Green procurement, PraC-03: Green distribution and reverse logistics, PraC-04: Government involvement.

Table 4.17 Correlation between green SCM practices and performance

	PraC-01	PraC-02	PraC-03	PraC-04	PerF-01	PerF-02

Practices						
PraC-01	1	0.353**	0.343**	0.519**	0.184	0.206*
PraC-02	0.353**	1	0.250*	0.295**	0.263**	0.233*
PraC-03	0.343**	0.250*	1	0.401**	0.257**	0.137
PraC-04	0.519**	0.295**	0.401**	1	0.198*	0.212*
Performance						
PerF-01	0.184	0.263**	0.257**	0.198*	1	0.772**
PerF-02	0.206*	0.233*	0.137	0.212*	0.772**	1

**Correlation is significant at the 0.01level (two-tailed)
*Correlation is significant at the 0.05 level (two-tailed)
PraC-01: Internal environmental management, PraC-02: Green procurement, PraC-03: Green distribution and reverse logistics, PraC-04: Government involvement, PerF-01: Environmental performance, PerF-02: Economic performance.

Table 4.18 Regression results between green SCM practices and pressure

Independent Variables		Dependent Variables							
		PraC-01		PraC-02		PraC-03		PraC-04	
		Unstandardized Coefficients (beta)	Multi-collinearity Statistics (VIF)	beta	VIF	beta	VIF	beta	VIF
Firm size		-.066	1.578	-0.070	1.587	-0.132	1.587	-0.235*	1.587
Industry section		0.130	1.586	0.216+	1.586	0.026	1.586	-0.043	1.586
PreS-01		0.422***	1.047	0.214*	1.047	0.184+	1.047	0.402***	1.047
PreS-02		0.122	1.046	0.015	1.046	0.160	1.046	0.281**	1.046
PreS-03		0.174+	1.072	0.108	1.072	0.170+	1.072	0.095	1.072

Adjusted R square		0.189		0.057		0.045		0.231	
F		5.747***		2.229+		1.968+		7.119***	

PerS-01: Regulation, PerS-02: Market, PreS-03: Internal factors, Pra-C01: Internal environmental management, PraC-02: Green procurement, PraC-03: Green distribution and reverse logistics, PraC-04: Government involvement.
+ p-value <0.10, * p-value <0.05, ** p-value <0.01, *** p-value <0.001

Table 4.19 Regression results between green SCM performance and practices

Independent Variables		Dependent Variables			
		PerF-01		PerF-02	
		Unstandardized Coefficients (beta)	Multi-collinearity Statistics (VIF)	beta	VIF
Firm size		0.152	1.585	0.306**	1.585
Industry section		0.018	1.605	0.026	1.605
PraC-01		0.015	1.501	0.058	1.501
PraC-02		0.208+	1.225	0.198+	1.225
PraC-03		0.184+	1.247	0.038	1.247
PraC-04		0.074	1.528	0.148	1.528
Adjusted R square		0.077		0.112	
F		2.425*		3.141**	

PraC-01: Internal environmental management, PraC-02: Green procurement, PraC-03: Green distribution and reverse logistics, PraC-04: Government involvement, PerF-01: Environmental performance, PerF-02: Economic performance.
+ p-value <0.10, * p-value <0.05, ** p-value <0.01, *** p-value <0.001

Table 4.20 Hypothesis description

Hypothesis	Supported/Not supported	Hypothesis	Supported/Not supported
H1a	Supported	***H2a***	Supported
H1b	Not supported	***H2b***	Not supported
H1c	Not supported	***H2c***	Not supported
H1d	Supported	***H2d***	Supported
H1e	Supported	***H2e***	Supported
H1f	Supported		
H1g	Supported		

4.4 Findings and discussion

The EFA was carried out by researcher to classify the factors of green SCM pressures/drivers, practices and performance. From Table 4.2-4.4, three factors on green SCM pressures/drivers were labelled as regulation, market, and internal factors; four factors on green SCM practices were labelled as internal environmental management, green procurement, Green distribution and reverse logistics, and government involvement; and two factors on green SCM performance were labelled as environmental performance and economic performance. In Table 4.5-4.7, the further reliability statistics confirm the reliability of the three factors of green SCM pressures/drivers, four factors of green SCM practices and two factors of green SCM performance.

The descriptive statistics indicate that the companies in Chinese construction industry have a variety of green SCM pressures and drivers that have impacts on the practices of green SCM. Each item listed in Table 4.7 can be regarded as the important items in the survey with mean values are all above 4.00 (agree) in the five-point Likert scale. *'Market'* is regarded as the most important or effective pressure in adopting or implementing green SCM practice. The factors of *'regulation'* (mean value is 4.28) and *'internal factors'* (mean value is 4.26) are also considered as important pressures and drivers. The companies in Chinese construction industry have significantly initiated implementing the practices of green supply chain management in terms of internal environmental management, green procurement, green distribution and reverse logistics, and government involvement, as driven by the green SCM pressures/drivers. However, the practices have been implemented at the early starts and have not resulted in significant improvement in the green SCM performance in Chinese construction industry, both economically and environmentally.

The green SCM pressures' ANOVA outcomes indicate that as a composite factor, only *'regulation'* has statistically significant differences among three firm sizes. The ANOVA results for green SCM practices do not show any statistically significant difference across the enterprises size. And the ANOVA results for green SCM performance present that the composite factor of *'economic performance'* has statistically significant differences among the firm sizes. Furthermore, the results of t-test show that the medium sized enterprises have the highest *'regulation'* pressure (mean=4.40), significantly stronger than small sized enterprises. And large sized enterprises haves slightly stronger *'regulation'* pressures than small sized enterprises. The t-test results also present the medium sized enterprise have the highest positive *'economic performance'* (mean=3.41), significantly higher than small sized enterprises and large sized enterprises also have significantly higher positive *'economic performance'* than small sized firms.

Both results of ANOVA and t-tests for green SCM pressures indicate that '*regulation'*, *'market'* are composite factors for both industry sectors, but the *'internal factors'* have slight differences between two Chinese construction industry sectors in terms of construction sector and building material sector. The construction sector enterprises have significantly stronger *'national (domestic) regulations'* pressure than building material sector companies. The construction sector enterprises have significantly stronger *'green image'* pressures than building material sector companies. And the construction sector enterprises have significantly stronger *'environmental policy'* pressures than building material sector companies. The results for green SCM practices also show only the composite factor of *'green procurement'* has statistically significant difference across the two different construction industry sectors, the practice of *'green procurement'* in building material sector are significantly stronger than in the construction sector companies. The item of *'environmental requirement*' is significantly different between two industry sectors. The construction sector enterprises have significantly stronger *'environmental requirement'* practices than building material sector companies. There is not any statistically significant difference between two industry sectors in other composite green SCM practices including *'internal environmental management'*, *'green distribution and reverse logistics'*, and *'government involvement'*. Finally, both the composite factors of green SCM performance, such as *'environmental performance'* and *'economic performance'*, do not have any statistically significant differences between two Chinese construction industry sectors.

The correlation analysis results show that a significant relationship exists between *'internal environmental management' and 'regulation'*, a strong relationship exists between *'government involvement'* and *'regulation'*, and there is a clear relationship between *'government involvement'* and *'market'*. In contrast, *'internal environmental management'* does not have significant correlations with *'market'* and *'internal factors'*. *'Green procurement'* does not have significant correlations with all factors of green SCM pressure in terms of regulation, market and internal factors. *'Green distribution and reverse logistics'* does not have significant correlation with the factor of green SCM pressure such as regulation, market and internal factors. And *'government involvement'* does not have significant correlation with *'internal factors'*. In addition, the relationship between green SCM practices and green SCM performance in the sample of Chinese construction industry is portrayed in Table 4.17 with the results of bivariate correlation using Pearson correlation coefficients. The result shows that a significant relationship between *'environmental performance'* and *'green procurement'*, a strong relationship between *'environmental performance'* and *'green distribution and reverse logistics'*, and a clear relationship between *'environmental performance'* and *'government involvement'*. The result also presents that a significant relationship between *'economic performance'* and *'internal environmental management'*, a strong relationship between *'economic performance'* and *'green procurement'*, and a clear relationship between *'economic performance'* and *'government involvement'*. In contrast, *'environmental performance'* does not have significant correlation with *'internal environmental management'*. And the *'economic performance'* does not have significant correlation with '*green distribution and reverse logistics'*.

In the regression models, each factor of the green SCM pressures/drivers, practices and performance were averaged from the underlying items of the measurement to form a single indicator factor. In Table 4.18, it shows that there is a clear and positive relationship between *'regulation'* and green SCM practices such as regulation has significantly positive influences on internal environmental management, green procurement and government involvement, and slightly positive influence on *'green distribution and reverse logistics'*. *'market'* is likely to have no significant influences on most of green SCM practice in terms of internal management, green procurement and Green distribution and reverse logistics, however, has a significantly positive influence on *'government involvement'*. The *'internal factors'* have slightly positive influences on *'internal environmental management'* and *'green distribution and reverse logistics'* but seem to not have any significant impacts on *'green procurement'* and *'government involvement'*. In addition, as the control variable, the firm size has a significantly negative impact on *'government involvement'*. In addition, it indicates that both *'environmental performance'* and *'economic performance'* seem to not have any significant relationships with each factor of green SCM practices such as internal management, green procurement, Green distribution and reverse logistics, and government involvement in Table 4. 19.. In particular, *'green procurement'* has slightly positive impacts on both *'environmental performance'* and *'economic performance'*. '*Green distribution and reverse logistics'* has a slightly positive influence on *'environmental performance'*. In addition, as the control variable, firm size has a significantly positive impact on *'economic performance'*.

Chapter 5 Case Studies

Case studies can generate holistic pictures of green SCM implementation. Multiple cases can increase external validity and help guard against observer bias. To gain enhanced depth and enhance insight into the causal relationship among factors obtained from the empirical studies, two case studies were conducted. Case one was with a Chinese building material manufacturer, Shandong Jinxiang Aluminium Corporation (SJAC), and the other one was with a Chinese real estate developer, Shandong Jinsheng Corporation (SJSC). To explore and identify best practices and gaps of green SCM practices and deliver grounded recommendations for future practices in Chinese construction industry, two further case studies were constructed on two British sustainable buildings.

5.1 Green supply chain management practices in Chinese construction sector

5.1.1 Case study 1: Shandong Jinxiang Aluminium Corporation

SJAC is the third largest producer of aluminium extrusion in China with corporate headquarters in Linyi, Shandong. This company was established in 1999, specializing in the production of architectural aluminium doors and windows, aluminium curtain walls and other industrial aluminium. SJAC has two aluminium extrusion production bases, covering an area of 420,000 square meters, and hires more than 2,600 employees. The company produces 550,000 square meters of aluminium across more than 400 types of products, and has an annual turnover of 4 billion RMB. The company is certified by ISO9001 international quality management system, ISO14000 environmental management, and 'Advanced Private Enterprise in Shandong Province'.

5.1.1.1 Green SCM drivers/pressures in Shandong Jinxiang Aluminium Corporation

- <u>Laws, regulations and polies</u>

Traditionally, building material manufacturers produce heavy pollutions in China, therefore, a number of laws and regulations were enacted. It requires all building material manufacturers to meet the social and environmental standards, such as air emissions below specified standards, using clear energy and improving environmental performance. SJAC is required to meet the following national environmental laws and regulations:

  - Act of the People's Republic of China on Environmental Protection (1989),

- Act of the People's Republic of China on Environmental Impact Assessment (2003),
- Act of the People's Republic of China on the Prevention and Control of Atmospheric Pollution (2000),
- Act of the People's Republic of China on the Prevention and Control of Water Pollution (2008),
- Act of the People's Republic of China on the Prevention and Control of Pollution from Environmental Noise (1997),
- Act of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste (2005),
- Cleaner Production Promotion Act of the People's Republic of China (2012),
- Act of the People's Republic of China on Water and Soil Conservation (2010),
- Regulation of the Administration of Construction Project Environmental Protection (1998),
- Notice of the State Council Approved the Issue of Acid Rain Control Zones and Sulphur Dioxide Pollution Control Zones (1998/5),
- Notice of the General Office of State Council, National Development and Reform Commission and Other Departments to Forward Notifications on Accelerating the Implementation of Cleaner Production (2003/100),
- Guiding Catalogue of Industrial Structure Adjustment (2011),
- Decision of the State Council on the Implementation of the Scientific Concept of Development to Strengthen Environmental Protection (2005/39),
- Notice on Regulating Consulting Fees Related to environmental impact issues (2002/125),
- Notice on Strengthening water conservation (2000/1015),
- Construction Project Environmental Impact Assessment Classification Catalogue (2008),
- Advices on the Implementation of Act of Clean Production Promotion of People's Republic of China (2003/60),
- Regulations on the Control over Safety of Dangerous Chemicals.

In addition, SJAC must meet following provincial environmental regulations:

- Procedures of Shandong Province for Implementing Act of the People's Republic of China on Environmental Impact Assessment (2006),
- Environmental Regulations, Shandong Province (2001),

- Shandong Province Environmental Protection “11th Five Year Plan” (2006/82),
- Notice of the General Office of the People’s Government of Shandong Province on Further Strengthening Environmental Impact Assessment and Construction Project Environmental Protection (2006/60),
- Advice of Environmental Protection Bureau of Shandong on Strengthening Environmental Impact Assessment (2007/31),
- Ecological Environment Construction and Protection Plan, Shandong Province (2003),
- Ecological Environment Construction Plan, Shandong Province (2003),
- Decision of State Council on the Implementation of Scientific Development Concept and Strengthening Environmental Protection (2005/39),
- Advice of the People’s Government of Shandong Province on Further Implementing the Decision of State Council on the Implementation of Scientific Development Concept and Strengthening Environmental Protection (2006/72),
- Notice of the People’s Government of Shandong Province on Further Strengthening Implementation of City Water Saving (2007/4),
- Notice of the People’s Government of Shandong Province on Implementation of Energy Conservation and Emission Reduction (2007/39),
- Notice of the People’s Government of Shandong Province on Pilot Test of Cyclic Economy (2007/8).

These environmental laws and regulations have imposed pressures for SJAC to implement and improve its green SCM practices. The recent green agendas of government have also forced SJAC eliminate backward production capacity expanded from 5,000 t/a TO 50,000 t/a and part of the capacity is established as a reverse logistic system that considers environmental effects in the whole product life cycle and enables the company to actively be engaged in recycling the end-of-life products from its customers. In addition to reduce waste and impacts on environment, the reverse logistics system offers a way to SJAC to reuse raw materials retrieved from returned products therefore save the cost. As a supplier, SJAC exports its products to U.S and Europe, which requires company to meet international environmental regulations, such as F019 Final Rule released by United States Environmental Protection Agency, and Regulation (EC) No.66/2010 of the European Parliament and of the Council. The environmental requirements from domestic and international regulatory bodies impose immense challenges on SJAC, but they also force the company to build competency in environmental dimension, and consequently improve and maintain its environmentally sound image.

- <u>Pressures from market</u>

SJAC has experienced motivational pressures and drivers from their domestic and foreign customers. The products exported to foreign market need to fulfil various environmental requirements, including reduced environmental impacts during the whole product life cycle, reduced negative impacts on consumption of the natural resources, reduced impacts on climate, health and environment.

To obtain factual and accurate information on the environmental impacts of the products and associated production processes, customers request visiting the plants of the company, observing the operations and evaluating the working environment of the employees. Furthermore, major requirements are made from customers in designing and developing products, including product functionalities, quality, reliability, durability and sources of raw materials. SJAC invested in the environmental friendly production line which reduces carbon emission by 28% and pollution to zero, which lead to an improved environmental image and a higher market share. The customers' expectations on company's environmental image have driven SJAC to initiate and implement green SCM practices.

- <u>Internal Factors-Corporate Social Responsibility</u>

Corporate Social Responsibility (CSR) has also been integrated into SJAC's business model. As part of CSR strategy, SJAC is committed to build sound green image, and has taken liabilities for responsible disposal hazardous materials by the ISO9001-2008 international quality management system certification and ISO14000-2004 environment system certification have paved the way for SJAC to establish a sound green image. The general managers Zhaoli Jiang of SJAC emphasised that the company has strived improve its CSR performance. SJAC develops source reduction strategies (Marien, 1998) in the hierarchy of 3R, i.e., reduce, reuse, recycle; and makes continuous improvement in reducing noise, water, air and solid waste pollution from their premises.

In summary, green SCM pressures and drivers, including regulations, market and internal factors such as CSR, drive SJAC to initiate and implement green SCM practices.

5.1.1.2 Green SCM practices in Shandong Jinxiang Aluminium Corporation

As a pioneer in Chinese building materials manufacturing industry, SJAC has initiated multiple dimensions of green SCM practices, including internal environment management, green procurement, green distribution and reverse logistics, and government involvement.

- Internal Environmental Management

Senior managers in SJAC put forward the green SCM practices of setting up green image of the company and integrating CSR policy into its business model. Designing and producing environmental friendly products is one key dimensions of green SCM practices for SJAC to gain and maintain its competitiveness. Aluminium products produced by SJAC are evaluated to be reliable and durable, offer dynamic functions, and have low energy consumption and carbon emissions. Since 2010, SJAC has invested about 10 million RMB to maintain and enhance the green image. SJAC purchased equipment from Japan, Italy and Switzerland to eliminate noise, purify emission, and treat water and solid waste responsibility. SJAC has completed a project for water and solid waste treatment through the inter-department cooperation, which is very important in Linyi which is a city suffering from heavy water and solid waste pollution. In addition, a system is purchased to monitor, evaluate and manage the production process to meet domestic, Japanese, U.S and EU environmental standards.

Certifications by ISO9001 and ISO14001 facilitate SJAC to meet the requirements of customers, minimize negative impacts on the environment, and comply with regulatory and statutory environmental requirements. Such certifications also help SJAC enter the global market, and improve quality of the product to meet the international standards. Environmental issues are the main concerns for SJAC during its product design, development and manufacturing. To address these concerns, SJAC has implemented cleaner production practices by closely cooperating with research institutes such as Shandong University, focusing on eco-design of products, waste prevention and source reduction.

Green manufacturing process is also developed by SJAC, to achieve production efficiency, reduce environmental and occupational safety expenses, and lower raw material costs. Green manufacturing practices encompass following:

  - 3Rs: reduce, reuse and recycle materials such as aluminium, nickel, magnesium, silicon, hydrogen nitrate, sulphuric acid, coal and water;

- Energy efficient technology: 1) design product for using fewer resources, 2) improve equipment uptime, 3) increase product life span leading to higher productivity and efficiency, 4) reduce energy consumption;
- Hazardous substance control: 1) quality control and recheck before processing, 2) rinse parts with using reuse water instead of chemicals.

- <u>Green procurement</u>

SJAC collects the environmental information and sets up the database on environmental situations of the materials and components related to suppliers. JSAC believes green purchase is a concept of acquiring the selection of resources that minimizes negative environmental impacts, and a solution for both economically conservative ad environmentally concerned business. The supplier is assessed by SJAC to ensure they meet various environmental requirements and can supply environmental friendly materials continually. Green purchase practices adopted by SJAC include:

- Green supplier selection: SJAC select suppliers who meet environmental requirements and control hazardous resources responsibly;
- ISO 14000: SJAC prioritises suppliers who acquire ISO 14000 international environmental management certification or other environmental directives;
- Environmental requirement: SJAC purchase materials or parts that meet environmental quality standards or pass the audit process following environment-related regulations.

- <u>Green Distribution and Reverse Logistics</u>

Green distribution of SJAC consists of green packaging and green logistics, both of which are outsourced to achieve Just-in-time (JIT) production and require monitoring for the economic and environmental performance. The findings in green distribution practices include:

- Green Packaging: 1) promote reuse and recycle package, 2) encourage and adopt returnable packaging methods, 3) standardize packaging, 4) downsizing packaging;
- Green transportation: 1) distribute products together rather than in smaller batches, 2) optimise routing and minimise mileage to be travelled.

Practices of JSAC's reverse logistics include waste collection, disposal and reprocessing. The findings of JSAC's practices of reverse logistics include:

- Waste collection: SJAC initially inspects, selects and sorts the used parts which are shipped to recycle plants;
- Waste treatment: Water waste and solid waste are treated by Liuqing River Final Treatment/ Landfill Company using secure solidification and stabilization systems;
- Recycle Plants: SJAC owns a recycling plant that collects used parts from customers or manufacturing plants, and recycle metals such as aluminium, nickel, magnesium and silicon.

- Government Involvement

Government is involved with SJAC's green SCM practices as a facilitator, enabler and instructor. Government's involvement facilitates maximising the performance improvement resulted from the implemented green SCM practices, as evidence in the reduced toxic releases to the environment, and more effective use of renewable resources. The local government helps building materials manufacturers develop and implement 'Design for Energy Saving' scheme, which aims to reduce the energy consumption in the company. SJAC has also benefited from the technical assistances offered by government, such as workshops for energy conservations and minimising wastes generated from production. Furthermore, 'End-of-life' is also considered by the government that focuses on eco-design. The government has encouraged and fostered collaborations between research institutions and JSAC to investigate the ways of maximising the use of end-of-life products, including potential for materials retrieval, energy recovery, high recyclability, re-manufacturability and reusability. Through the coordination and cooperation of government, SJAC has developed innovative products that be reprocessed for raw materials, and achieve resource efficiency. The innovative design also eliminates the production of hazardous materials such as hydrogen nitrate and sulphuric acid.

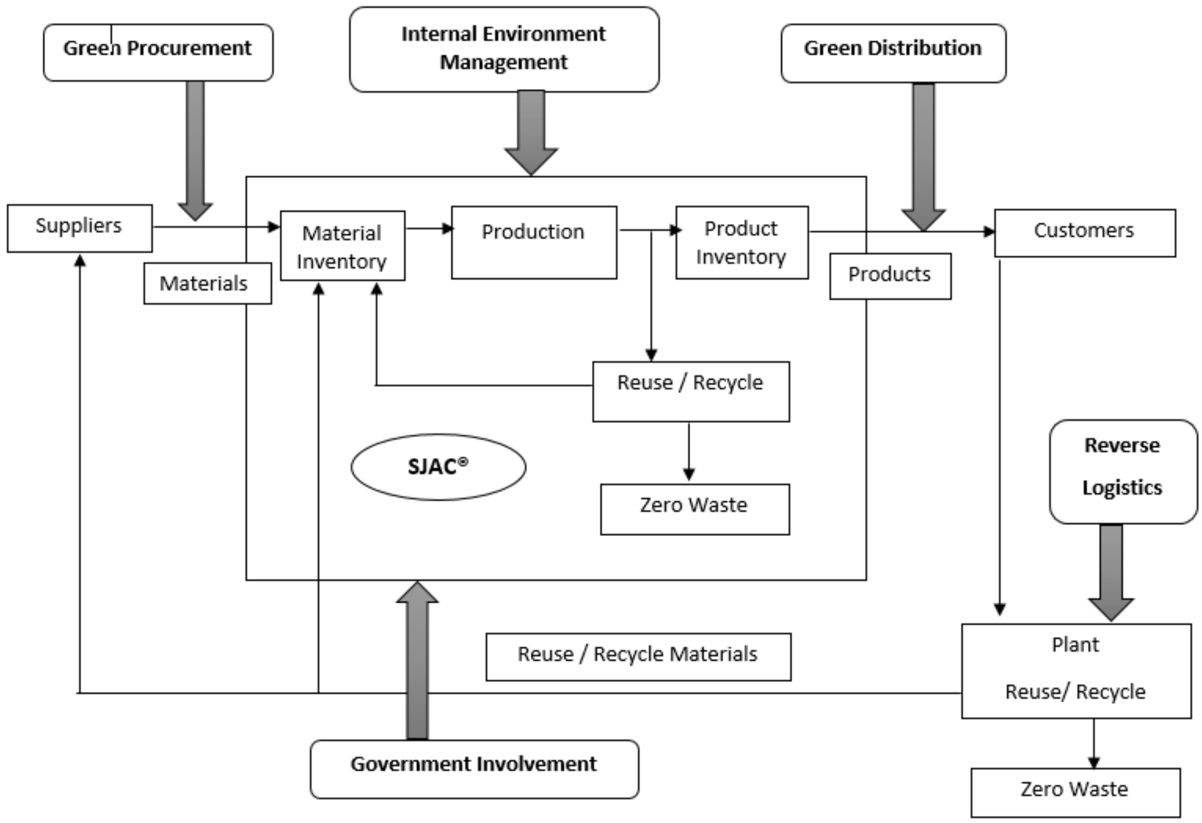


Figure 5.1 Green SCM practices of Shandong Jinxiang Aluminium Corporation

5.1.1.3 Green SCM performance in Shandong Jinxiang Aluminium Corporation

SJAC's green SCM practices have improved both environmental and economic performances, which have been recognised through various awards and initiatives achieved. In specific, the production capacity has expanded from 5,000 t/a to 50,000 t/a. However, the consumption of hazardous materials such as sodium hydroxide and ammonium acid fluoride have significantly reduced (Table 5.1). The consumption of water and coal fuel is also decreased clearly. On the other hand, there is a clear increase of the consumption of clean energy such as gas and steam that are from 100,000 M3/a to 1,3500,000 M3/a, and from 0 t/d to 6.6 t/d (Table 5.1). furthermore, the air emission has reduced obviously, for examples, sulphur dioxide decreases from 2.6786 t/a to 0.251 t/a, smoke/dust decreases from 15.445 t/a to 2.4088 t/a, nitric acid fog decreases from 0.113 t/a to 0.013 t/a, sulphuric acid fog decreases from 3.3 t/a to 0.46 t/a, chromic acid fog decreases from 0.013 t/a to 0.0014 t/a, and hydrofluoric acid fog decreases from 0.25 t/a to 0.058 t/a (Table 5.2). Additionally, the production of solid and water waste reduced obviously, and SJAC has achieved ‘Zero Waste Discharge’ for solid waste, hazardous solid waste and water waste (Table 5.3)

The environmental performance improvement has been recognized as an ‘Environmental Protection Model Company’ by Shandong province government. SJAC has also been nominated as ‘The Branded Enterprise in Shandong Province’, and received awards for ‘The Branded Trademark in Shandong Province’, ‘High-tech Private Enterprise’ and ‘Advanced Private Enterprise in Shandong Province’ by local and province government. Its products are awarded as ‘Shandong Energy Efficient and High-Performance Product’ and ‘Shandong Branded Product’. Such awards have greatly improved both environmental and economic image of SJAC and enlarge its market share in China, Australia, Southeast Asia, Europe and North America.

According to Environmental Impact Report on SJAC (2011), the company’s products and production meet requirements of carbon emission standards, cleaner production standards, and solid waste standards. As of Water Waste Assessment Report on SJAC (2011) and Environmental Assessment Report on SJAC (2012), its products meet water waste standard and safety of dangerous chemicals standard. SJAC has achieved ‘Zero Waste Discharge’ for water, solid, and toxic substances. Although there is no factual financial data indicating how the green SCM practice implementations contribute to market share increment and associated positive economic performance, it is fair to say that without meeting certain environmental requirements in its products and production SJAC probably have lost in the competition with competitors.

Table 5.1 SJAC's consumption of materials and energy

	Ton per Annum (t/a) Ton per Day (t/d) Kwh per Annum (Kwh/a) m^3 Per Annum (m^3/a)	Before 2011	From 2012
Production Capacity	t/a	5,000	50,000
Materials			
Aluminium	t/a	4,990	49,900
Silicon	t/a	25	250
Magnesium	t/a	35	350
Refining Agent (20% Carnallite, 20% Calcium fluoride)	t/a	2.67	26.67
Covering agent (25% Polycrystalline silicon, 30% Sodium Chloride, 45% Potassium chloride)	t/a	2.67	26.67
Dregs Remover (30% Polycrystalline silicon, 20% Sodium Chloride, 30% Potassium chloride)	t/a	2.67	26.67

Water	t/a	227.6*	850*
Hazardous Materials			
Sulphuric Acid (98%)	t/a	250	2,500
Nitric Acid	t/a	0.5	5
Hydrofluoric Acid	t/a	0.833	8.33
Phosphoric Acid	t/a	1.666	16.66
Nickelous Sulfate	t/a	4	40
Nickel Difluoride	t/a	2.5	25
Chromium Trioxide	t/a	10	100
acrylic Resin	t/a	416	4,160
Sodium Hydroxide	t/a	45*	40*
Ammonium Acid Fluoride	t/a	4.0*	0*
Energy			
Electricity	10,000 Kwh/a	485	4850
Gas	10,000 m^3 /a	10*	135
Coal Fuel	t/a	1174.8*	868
Steam	t/d	0*	6.0*

Table 5.2 SJAC's air emission

	Ton per Annum (t/a)		
		Before 2011	From 2012
Production Capacity	t/a	5,000	50,000
Sulphur Dioxide	t/a	2.6786*	0.251*
Smoke/ Dust	t/a	15.445*	2.4088*
Nitric Acid Fog	t/a	0.113*	0.013*
Sulphuric Acid Fog	t/a	3.3*	0.46*
Chromic Acid Fog	t/a	0.013*	0.0014*
Hydrofluoric Acid Fog	t/a	0.25*	0.058*
Nitrogen Oxides	t/a	No record	0.5271
Fluoride	t/a	No record	0.0286
Non-methane Hydrocarbon	t/a	No record	0.0228

Table 5.3 SJAC's solid and water waste

	Ton per Annum (t/a) m^3 per day (m^3/d)	Before 2011		From 2012	
Production Capacity	t/a	5,000		50,000	
		Production	Discharge	Production	Discharge

Solid Waste	t/a	877.68*	0	5,122.85*	0
Hazardous Solid Waste	t/a	3.9	0	38.8	0
Water Waste	m^3 /d	178*	0	623.9*	0

5.1.2 Case study 2: Shandong Jinsheng (Group) Corporation

SJSC is one of the top 500 private enterprises in China, was founded in 1993 and headquartered in Linyi, Shandong Province, China. The company operates in three major sectors, including real estate development, copper smelting production, and financial guarantee. SJSC has more than 860 employees, annual turnover of over 12 billion RMB. In 2014, the sector of real estate development had annual revenues of 1.3 billion RMB (10.4%), the sector smelting production had annual revenues of 10 billion RMB (80%), and the sector of financial guarantee has annual revenues of 1.2 billion RMB (9.6%). The company is certified by ISO9001 international quality management system, ISO 14000 environmental management, and is awarded 'AAA Credit Rating Enterprise' by Agricultural Bank of China.

5.1.2.1 Green SCM drivers/ Pressures in Shandong Jinsheng Corporation

- Laws, regulations and polices

Similar as building material manufacturer SJAC, real estate developers are also the traditional heavy polluter in China. According to statistics, construction waste accounts for 30% to 40% of the total urban waste in China (He and Su, 2011). Similar as the building material manufacturing sector, real estate developers also need to abide environmentally related laws and regulations that require them to meet the environmental standards, including saving energy, using cleaner energy and enhancing environmental management. As a real estate provider, SJSC is required to meet the flowing national environmental laws and regulations:

- Act of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste (2005),
- Act of the People's Republic of China on of Environmental Protection (1989),
- Regulation of the Administration of City Appearance and Environmental Sanitation (1992/101),
- Regulation of Administration of Urban Construction Garbage (2007),
- Cleaner Production Promotion Act of the People's Republic of China (2012),
- Green Building Action Plan (2013/1),

- Notice of the State Council for the 12th Five years plan of Energy Conservation (2011/26),
- Notice of Ministry of Commerce, Ministry of Public Security, Ministry of Construction, Ministry of Transportation about Administration of Mixed Concrete in Urban Area (2003/341),
- Notice of Ministry of Commerce, Ministry of Public Security, Ministry of Public Security, Ministry of construction, Ministry of Transportation, General Administration of Quality Supervision, Inspection and Quarantine, Environmental Protection Bureau about Administration of Mixed Concrete in Urban Area (2007/205),
- Notice of Ministry of Commerce, Ministry of Housing and Urban-Rural Development about Administration of Mixed Concrete in Urban Area (2009/361).

In addition, SJSC should also meet the following provincial and local environmental regulations:

- ‘12th Five Year Plan’ of Building Energy Efficiency of Linyi,
- Ready-mixed Mortar Planning of Linyi (2014-2018),
- Regulation of the Bulk Cement Development of Shandong Province (2011/219),
- Notice of the General Office of the People’s Government of Shandong Province about Administration of Mixed Mortar and in Urban Area and popularisation of Bulk Cement in Rural Area (2009/149),
- City Planning of Linyi 2005-2020,
- Construction Planning 2011-2015,
- Procedure of Administration of Ready-mixed Mortar of Linyi 2014-2018,
- Regulation of Green Construction in Linyi (2009),
- Procedure of Green Building Implementation in Linyi (2013)
- Regulation of Building Energy Conservation of Shandong Province (2013),

SJSC has implemented and improved its green SCM practices that are required by the environmental laws and regulations. The green SCM practices are also driven by the financial support from local government, for example, Linyi Government has released the ‘Financial

Incentives for Green Building and Green Eco-city' in 2015. The financial incentives from local government and legal requirements have driven SJSC to improve and maintain its environmental sound image.

- Pressures from market

Customers' requirements or expectation on energy efficient buildings were also seen as pressures or drivers that motivate SJSC to implement environmental practices. Customers call for a synergistic and integrated design in retrofitting of existing construction and to new structures that can ultimately eliminate and reduce the impacts of building on the human health and environment, for example, having plants in the rain gardens, building green roofs, reducing rainwater run-off, and using sunlight through photovoltaic equipment including active and passive solar. Furthermore, customers expect use energy-efficient building materials such as permeable concrete or packed gravel, and other low-impact building materials rather than conventional asphalt or concrete. To meet the expectations from real estate developers like SJSC need to have a thorough knowledge on energy efficient buildings in terms of design and construction, and the workforce need to be comprehensive and contemporary skills for waste and toxics reduction, indoor environmental quality, materials and energy efficiency, operation and maintenance optimisation.

- Internal Factors-Corporate Social Responsibility

Similar as building materials manufacturers, CSR has been integrated into real estate developers' business model. As part of CSR strategy, SJSC is committed to reduce the environmental impact of building, take advantage of renewable resources, and set up its environmentally sound image. ISO14000 environmental system certification and ISO9001 international quality management system certification have been embedded into the SJSC's environmental strategy, and are followed strictly to develop the environmental sound image. SJSC integrates the life-cycle of construction into the environmental strategy, by considering the pollution and waste produced, and energy consumed by raw materials which are used at different stages of the construction supply chain.

In summary, SJSC has implemented a range of green SCM practices, which are motivated by domestic environmental laws and regulations, customers' environmental requirements, and its internal factors such as CSR.

5.1.2.2 Green SCM practices in Shandong Jinsheng Corporation

As an outstanding private enterprise in Chinese real estate developer, SJSC takes the lead in initiating and implementing green SCM practices to improve its corporate image, and these practices are internal environmental management, green procurement, green distribution and reverse logistics, and government involvement.

- Internal Environmental Management

Environmental implications of construction practices are considered by the management team of SJSC because of pressures from markets and regulatory bodies, non-availability and increased costs of building materials, and increasing statutory requirements. Construction is much more complex process than manufacturing. SJSC employs advanced technologies and practices in constructing green buildings to reduce waste reduction, enhance indoor environmental quality, and improve materials efficiency, water efficiency and energy efficiency.

This company seeks to reduce waste of materials, water and energy during construction. For example, one goal of SJSC is to reduce the amount of materials such as timber going to landfills. SJSC collaborates with other companies to reduce the impacts on the water system, for example, they have worked with a car wash company to reuse the wastewater to wash cars. In the green buildings, wastewater is recycled and reused to flush toilet and for irrigation. Another recycling approach is to feed wastewater into the centralised wastewater treatment system which can produce artificial fertilizer using the wastewater. An increasing complex assessment method such as Life Cycle Assessment (LCA), which considers several factors of a product, such as waste, water pollution, air pollution, resource use and embodied energy, is implemented to assess a full range of implications of SJSC's activities.

SJSC provides optional designs to its customers to build up a high performance luminous environment through the integration of air flow control, exterior wall external insulation system, electronic light and day light sources, which can aid in increasing thermal quality, lighting quality, and energy performance of building. The high-performing and cost-effective building materials and renewable resources have been adopted by SJSC in its construction projects, including the permeable concrete, packed gravel, passive or active solar, and photovoltaic equipment. To control the indoor air quality, SJSC takes account into the integration of adequate ventilation, well-insulated and tightly sealed construct when they design buildings.

SJSC also requests its contractors to use recycled industrial productions, including demolition debris, foundry sand, and coal combustion products in construction projects.

- Green Procurement

Buildings are much more complex products that are composed by a multitude of materials, resources and components. SJSC implemented the green procurement, of which the first stage is a LCA of the environmental impacts for product or material SJSC would like to purchase. Once the assessment is done and the pollution level of the product is acceptable, the second stage of the green procurement policy requires the procurement team to consider material efficiency, waste to be produced and cost. In addition, green procurement activities of SJSC encompass following:

  - Green Supplier selection: an external body verifies information submitted by SJSC's suppliers who implement 3Rs (reducing, recycling and reusing) and hazardous chemicals control and obtain green certificate achievements.
  - ISO14000: 1) SJSC has implemented an ISO14000 Environmental Management System since 2000, which requires the development of SJSC's green procurement policy. 2) SJSC consider suppliers who acquire ISO14000 certification.
  - Environmental requirement: SJSC purchases building materials, components and equipment with environmental quality standards or passing the audit process following environment-related regulations.
  - Green procurement process: 1) paperless order, 2) recycle and reuse paper and plastic box.

- Green Distribution and Reverse Logistics

The practices of SJSC's green distribution involves green packaging and green transportation that increase space utilisation and lower materials usage and the amount of handling required. Green distribution practices adopted by SJSC include:

  - Green packaging: 1) standardise and downsize packaging; 2) encourage reusable packaging methods; 3) innovate 3R's programs.

- Green transportation: 1) give priority to local suppliers when ordering building materials, components and equipment; 2) direct delivery; 3) energy effective vehicles is a prime consideration.

The SJSC's reverse logistics activities are related to the reuse and recycle of its building materials. The findings in SJSC's reverse logistics practices include:

- Final treatment: the construction waste is treated by landfill companies who have industrial waste treatment and disposal systems.
- 3Rs during construction: 1) reduce indirect materials; 2) recycle excess inventory and materials; 3) promote reuse of parts.
- Techniques utilization: eco-design considers potential returnable construction components.

- Government Involvement

Government involvement is necessary due to real estate providers are unwilling to implement green SCM practices because of their difficulty in quantifying environmental costs, lack of knowledge, and perception of limited benefits and additional costs (Foo, 1997). The SJSC's compliance with government involvement can be facilitated, and uncertainties and risks reduced. However, home/building energy efficiency has become a national infrastructure priority in China, local governments organise workshops and offer guidelines and framework for implementing green SCM practices and suggest measures to be taken. The national and provincial governments provide leadership by increasing awareness of environmental protection, such as encouraging companies utilize ISO 14000 environmental Management System, adopting effective materials management, and suggesting building should be designed and constructed with the environmental considerations. Local governments also offer financial incentives to develop building assessment system, encourage innovative techniques, enhance environmental awareness, and popularize knowledge on green buildings. Through cooperation with local governments, SJSC has moved its focus from end-of-pipe pollution clean-up to environmental prevention through waste minimization and cleaner production; from costs and uncertainties of green SCM implementation to greatly accountable and transparent production. SJSC has perceived green SCM implementation as a CSR and business opportunity to enhance its competitive advantage and improve its corporate image.

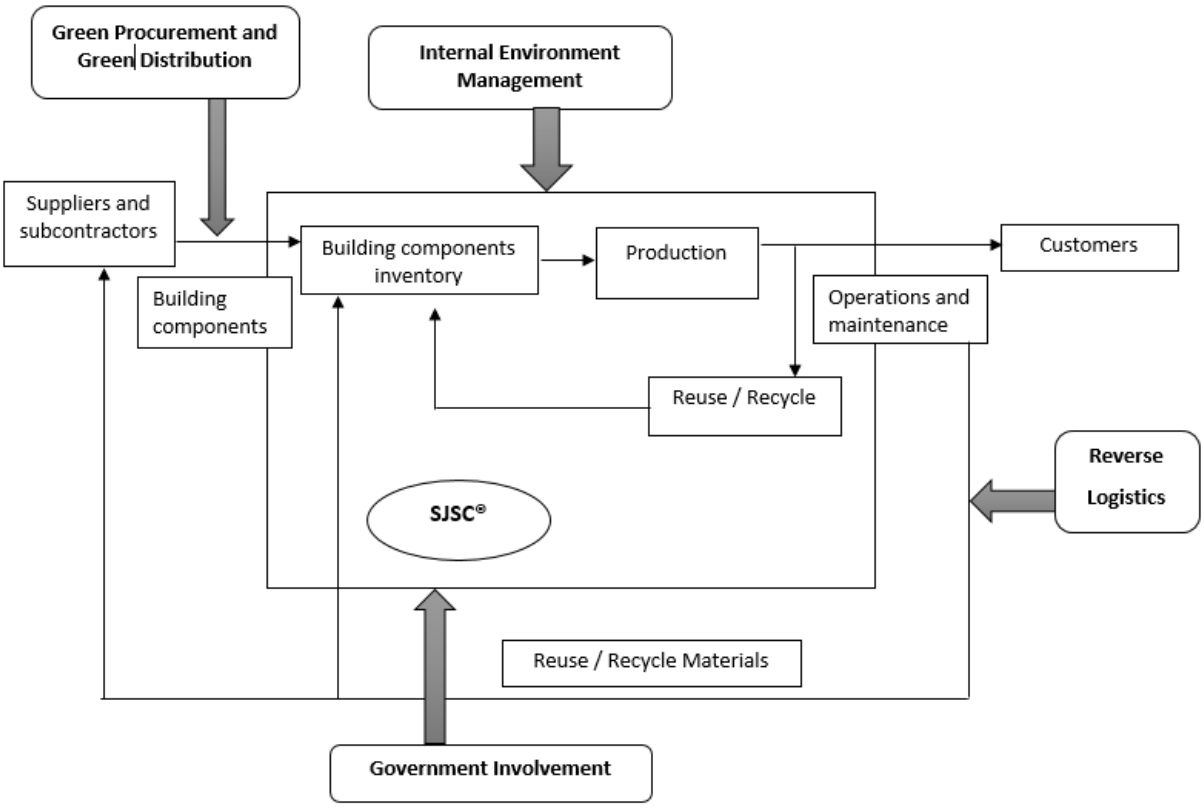


Figure 5.2 Green SCM practices of Shandong Jinsheng Corporation

5.1.2.3 Green SCM performance in Shandong Jinsheng Corporation

SJSC has improved both environmental and economic performance through green SCM practices. Jinglian Wang, the President of SJSC (2015) says 'real estate sector of SJSC has gained economic benefits, including avoidance of regulatory penalties, more competitive productions, green image, awards, expanded market share and increased revenues through environmental sustainability actions'. Furthermore, according to the SJSC Energy Efficiency of Residential Buildings Assessment Reports (2006-2014), the shape coefficient of building, overall heat transfer coefficient of building envelops, shading coefficient of window (East and West), and heating loss index of building have reduced markedly (Table 5.4-5.8), and there is an evident increase of the efficiency of boiler (Table, 5.9) which indicates a significant improvement of energy efficiency of buildings.

The environmental and economic performance improvement is also supported through awards and financial incentives achieved, which greatly improve SJSC's corporate image and enlarge its market. According to the Annual Report of SJSC (2014), the annual turnover of the sector of real estate development of SJSC has increased from 0.34 billion RMB in 2007 to about 1.3 billion RMB at the end of 2014. Compared to the building constructed before 2012, the energy consumption of residential buildings has reduced 65% based on the 'Residential Building Energy Efficiency Design Standards of Shandong Province DBJ14-037-2012'. The environmental performance has obtained SJSC the award of 'Environment-friendly Enterprise of Shandong Province', 'Outstanding Contribution to Energy efficiency in Shandong Province', and 'Sustainable Development Model of Shandong Province'. Such awards have greatly improved environmental and economic image of SJSC. SJSC will continue to perform both environmental and economic performance with increasing green SCM practices.

Table 5.4 SJSC's Shape Coefficient of Building

≤3 Floors Building		4-6 Floors Building		7-8 Floors Building		9-13 Floors Building		≥14 Floors Building	
2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013
0.40	0.52	0.35*	0.33*	0.35*	0.33*	0.30	0.30	0.30*	0.26*

Table 5.5 SJSC's Area Ratio of Window to Wall

	2006-2012	From 2013
North	0.30	0.30
East and West	0.35	0.35
South	0.50	0.50

Table 5.6 SJSC's Overall Heat Transfer Coefficient of Building Envelop

		Heat Transfer Coefficient W/（㎡·K）					
		≤3 Floors Building		4-8 Floors Building		≥9 Floors Building	
		2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013
Roof		0.45*	0.35*	0.55*	0.45*	0.55*	0.45*
Wall		0.50*	0.45*	0.63*	0.60*	0.63	0.70
Floor	External	0.50*	0.45*	0.65*	0.60*	0.65*	0.60*
	Internal	0.50	0.50	0.65	0.65	0.65	0.65

Door		1.7	1.7	1.7	1.7	1.7	1.7
Window	Cq≤0.2	2.8	2.8	2.8	3.1	2.8	3.1
	0.2≤Cq≤0.3	2.8*	2.5*	2.8	2.8	2.8	2.8
	0.3≤Cq≤0.4	2.8*	2.0*	2.8*	2.5*	2.8*	2.5*
	0.4≤Cq≤0.5	2.8*	1.8*	2.8*	2.0*	2.8*	2.3*
Wall (between Heating and Non-heating)		1.7*	1.5*	1.7*	1.5*	1.7*	1.5*
Door (between Heating and Non-heating)		2.0	2.0	2.0	2.0	2.0	2.0

Table 5.7 SJSC's Shading Coefficient (SC) of Window (East and West)

Area Ratio of Window to Wall (Cq)	Shading Coefficient	
	2006-2012	From 2013
0.3<Cq≤0.4	0.90*	0.45*
0.4<Cq≤0.45	0.90*	0.45*

Table 5.8 SJSC's Heat Loss Index of Building

Heat Loss Index (W/㎡)			
≤3 Floors Building	4-8 Floors Building	9-13 Floors Building	≥14 Floors Building

2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013
14.14	14.2	14.14*	13.2*	14.14*	11.7*	14.14*	10.5*

Table 5.9 SJSC's Efficiency of Boiler

		Efficiency of Boiler (%)													
Boiler Capacity (MW)		0.7		1.4		2.8		4.2		7.0		14.0		>28.0	
		2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013	2006-2012	From 2013
Fuel Coal	II	\	\	\	\	78	73	78	74	78	78	78*	79*	78*	80*
	III	\	\	\	\	78	74	78	76	78	78	78*	80*	78*	80*
Fuel Gas and Oil		89	86	89	87	89	87	89	88	89	89	89*	90*	89*	90*

5.2 Green supply chain practices in British construction sector

5.2.1 Case Study 3: Sustainable building using cooked oil to generate electricity

Case study 3 is about a building constructed for a consultancy company in London. The environmental requirements imposed by the UK Building Research Establishment Environmental Assessment Methodology (BREEAM) require the design of the building to be compliant with the Building Regulation (2006), and to achieve a 22% reduction in carbon emission. To be compliant with Zero-carbon Standards (2006), the design company adopted a few innovative approaches to reduce the energy consumptions, for example, using cooked oil to generate electricity, which reduces energy used by 18%; using shared open plan office which reduces the total capacity needed and, the building materials needed. The consultancy company, as the owner of the building, aims to establish their green corporate image by using it as their main office, therefore, the consultancy company had an active involvement in the building design and construction. Under the guidance from BREEAM, and following the requirements from the consultancy company, the construction company sources more environmentally friendly materials from suppliers that are certified by ISO14000. They also established strong collaborative relationships with the design company, to ensure construction meets the design standards and requirements.

5.2.1.1 Green SCM drivers/pressures

The drivers for achieving the high-level sustainability are identified as:

- Regulation：Building Regulation (2006); Zero-carbon Standards (2006); Display Energy Certificate (2008)
- Market: stakeholder’s pressure; customer expectation
- Internal factors: green image.

5.2.1.2 Green SCM practices

The high-level sustainability of the building is mainly achieved as a result of the following green SCM practices:

- Environmental Management

The management team of the consultancy company integrates CSR policy to put forward the green SCM practices. Close communication with project team, facade engineers, building engineers, architects, BREEAM assessor and building users to develop the design that can deliver operational carbon savings. Management is based on the effective use of resources that are monitored to improve energy efficiency and reduce carbon emission on the regular basis. For example, water consumption is monitored for all building users on monthly basis which is in place to save water and money.

- Green Procurement

The green procurement policy requires the procurement team to consider material efficiency, waste to be produced and cost. In addition, green procurement activities including:

  - Green Supplier selection: 1) an external body verifies information submitted by suppliers who implement 3Rs (reducing, recycling and reusing) and obtain green certificate achievements; 2) second-tier suppliers' environmental assessment.
  - ISO 14000: suppliers who acquire ISO 14000 certification or other environmental directives;
  - Environmental requirement: building materials, components and equipment should be with environmental quality standards or passing the audit process following building regulations.
  - Green procurement process: paperless order.

- Green Distribution and Reverse Logistics

The practices of green distribution involve green packaging and green transportation that includes a number of practices as following:

  - Green packaging: 1) standardise and downsize packaging; 2) encourage recycle packaging methods; 3) innovate 3R's programs.
  - Green transportation: 1) give priority to local suppliers; 2) direct delivery; 3) energy effective vehicles is a prime consideration.

The reverse logistics activities are related to the reuse and recycle of its building materials, including:

- 3Rs during construction: 1) reduce indirect materials; 2) recycle excess inventory and materials; 3) promote reuse of parts.
- Techniques utilization: eco-design considers potential returnable construction components and building maintenance.

- Government Involvement

The environment can be damaged by buildings with inefficient energy use. The UK government has deployed an array of policies to reduce building energy consumption and improve building energy efficiency. For example, the UK government tightens the requirements of energy efficiency within the Building Regulation (2006) to limit on Thermal Conductivity in new buildings, and promotes the improvements of public building energy efficiency within Display Energy Certificate (2008) to promote the improvement of public building energy efficiency.

5.2.2 Case Study 4: A green and environmental friendly building for a public sector organisation

Case study 4 is a library built for a Higher Education Institution in the UK. The building is designed to meet the targets of the sustainable development in the institution, by incorporating the BREEAM targets into the design process. The building is designed to achieve the BREEAM excellent rating and ensure that the project process is in place to gain the sustainable outcomes through close work with the BREEAM assessor and design team from the earliest stages of the project. The construction phase has focused on using sustainable construction methods and practices, minimising environmental impacts, managing and monitoring water, energy and waste consumption. Under the requirements and the guidance from BREEAM, the construction company sources more environmentally friendly materials from suppliers that are certified by ISO14000. It is a highly-performing building with a number of zero carbon solutions, for example, a lighting control system is fitted to increase user control and reduce energy consumption; ventilation is predominately natural, with areas served by mechanical ventilation to ensure good ventilation rates and thermal comfort; the building features such sustainable technology as rainwater harvesting and storage system which captures and reuse water to serve the toilet flush system; and the landscape design and planting delivering a nature garden area that maximises biodiversity enhancement of the site.

5.2.2.1 Green SCM drivers/pressures

The drivers for achieving the high-level sustainability are identified as:

- Regulation: Building Regulation (2006); Zero-carbon Standards (2006); Display Energy Certificate (2008)
- Market: Stakeholders' pressure; customer expectation
- Internal factors: Green image.

5.2.2.2 Green SCM practices

The high-level sustainability of the building is mainly achieved as a result of the following green SCM practices:

- Environmental management:

Environmental implications of green SCM practices are considered by senior management, mid-level management, project team, design team and BREEAM assessor who are committed to and supports environmental practices. Stakeholders utilize advanced methods and practices in designing and constructing buildings to meet Building Regulation (2006), which seeks to reduce carbon emission. For example, passive techniques including heat recovery, lighting control, and rainwater collection systems allowed more than 20% reduction in carbon emission. Green construction process is also developed to reduce environmental and occupational safety expenses, including:

  - 3Rs: 3Rs during construction: 1) reduce indirect materials; 2) recycle excess inventory and materials; 3) promote reuse of parts.
  - Energy efficient technology: eco-design considers potential returnable construction components and building maintenance.

- Green procurement

In this case, green procurement is regarded as a concept of acquiring the selection of resources that minimizes negative environmental impacts, and a solution for environmentally concerned business. Suppliers should meet various environmental requirements and can supply environmental friendly materials continually.

  - Green supplier selection: suppliers should meet environmental requirements and obtain green certificate achievements responsibly;
  - ISO 14000: the construction company sources more environmentally friendly materials from suppliers and/or second-tier suppliers that are certified by ISO14000;
  - Environmental requirement: purchased materials or parts should meet environmental quality standards or pass the audit process following environment-related regulations.

- Green Distribution and Reverse Logistics

Green distribution consists of green packaging and green logistics in this case, both of which are outsourced to require monitoring for environmental performance. The findings in green distribution practices include:

  - Green Packaging: 1) promote recycle package, 2) encourage and adopt recycle packaging methods, 3) standardize packaging;
  - Green transportation: 1) give priority to local suppliers; 2) energy effective vehicles is a prime consideration, 3) optimise routing and minimise mileage to be travelled.

Practices of reverse logistics include waste collection and techniques utilization. The findings reverse logistics practices include:

  - Waste collection: used parts are inspected, selected and sorted which are shipped to recycle plants;
  - Techniques utilization: eco-design considers potential recycle construction components and building maintenance.

- Government Involvement

Government acts as an enabler and instructor in green SCM practices. The UK government has releases Building Regulations (2006) and Zero-carbon Standards (2006), which aims to reduce the carbon emission, and the public building energy efficiency is enhanced by Display Energy Certificate (2008).

Table 5.10 Green SCM practices in British construction sector

Key competencies	**Activities**
Environmental management	Commitment and support for green SCM from mid-level and senior management; project team, design team, construction companies and BREEAM assessor are committed to and supports environmental practices, including ISO14000 certificate, BREEAM rating, 3Rs, energy efficient technologies, renewable resources adoption, cooperation with customers for green design/production.
Green procurement	Suppliers' ISO14000 certification, second-tier suppliers' environmental assessment, environmental audit for suppliers, cooperation with suppliers for green purchasing, providing environmental requirements to suppliers, cooperation with suppliers for environmental improvement
Green distribution and reverse logistics	Cooperation with customers for environmental objectives (green packaging, green transportation), dispose of excess materials/ inventories, dispose of used/ scrap materials
Government involvement	Providing guidelines and standards for reduction of carbon emission, building energy efficiency is the UK's policy to reduce carbon emission

Chapter 6 A Comparison of Chinese and British Construction Sectors through Benchmarking Exercise

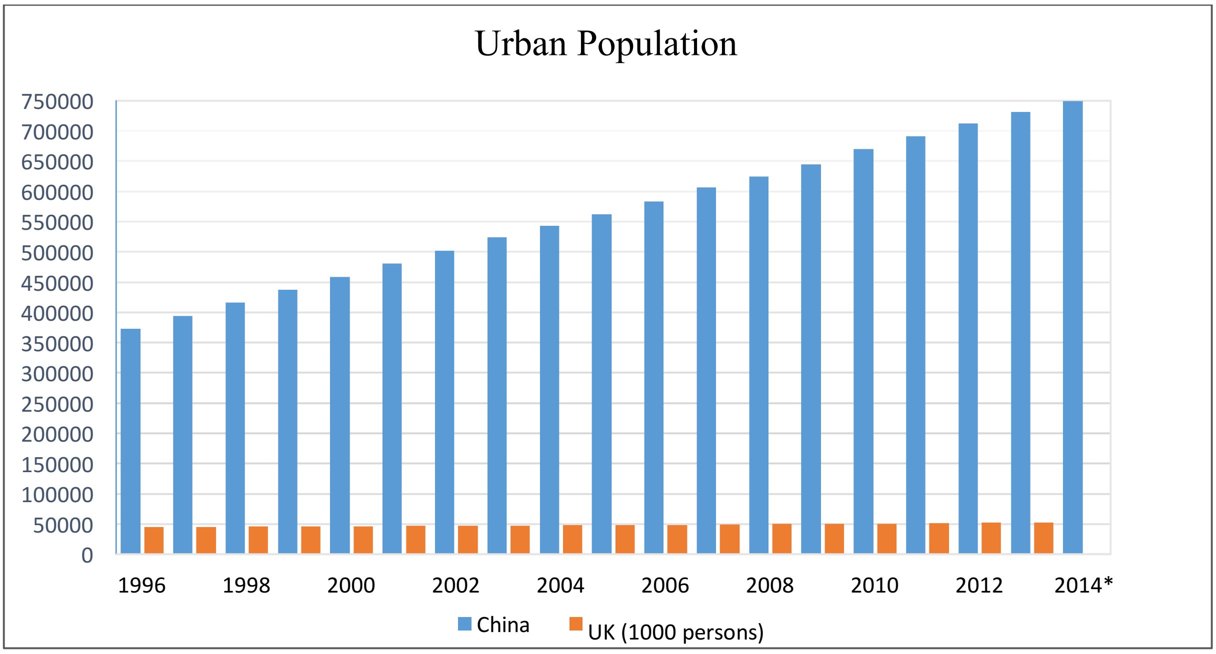
6.1. A comparison on demographics, climate, and timelines

The demographic factors (including population size, trends, growth and migration), climate and comparative timeline of introducing energy and building regulations have influences on demands on new buildings, growth of construction SC, and the energy consumed.

6.1.1 Demographics

China and UK differ significantly in population size, population trends, population growth, migration (e.g. Chinese young generations move from rural areas to urban areas, which place a high demand on constructing new buildings, and pressure on environment), etc. China has the world's largest population. The population growth has slowed down since the one child family planning policy was initiated in the late of 1970s. However, the urbanisation process is accelerating in China. As shown in Figure 6.1, urban population of China has increased from 373.04 million in 1996 to 749.16 million in 2014 (National Bureau of Statistics of China, 2015). This urbanisation process has a large impact on Chinese construction industry and China's energy consumption. As Figure 6.2 shows, the speed of China's construction is impressive. The floor space completed by construction enterprises has increased from 373.04 million square meters in 1996 to 749.16 million square meters in 2014 according to the data from National Bureau of Statistics of China 2015. As Chmutina (2010) states, buildings play an important role in the energy demand sector. As Figure 6.3 presents, with the increase of Chinese construction, the domestic energy consumption has increased from 177.135 million tons of Oil Equivalent (OE) to 277.662 million tons of SCE in 2012 according to the data from National Bureau of Statistics of China 2015.

In contrast, the population of the UK is the 22nd largest in the world, was around 63.182 million in 2011 (Office for National Statistics, 2012). The total population of UK has a slow increase, from 58.18 million in 1996 to 64.1 million in 2013 according to the data from World Bank. The UK's urban population was slightly above 78% of the total population in 1980s, as shown in Figure 6.1 presents. From 1996 to 2013, the population size has a slow increase from 45.37 million in 1996 to 52.56 million in 2013 (World Bank, 2015). The UK's domestic energy consumption is fluctuated around 45 million tons of OE as Figure 6.3 shows.



*The statistics of the UK's urban population of 2014 have not been published by June 2015.

Figure 6.1 Urban Population in China and UK 1996-2014 (National Bureau of Statistics of China, 2015; World Bank, 2015)

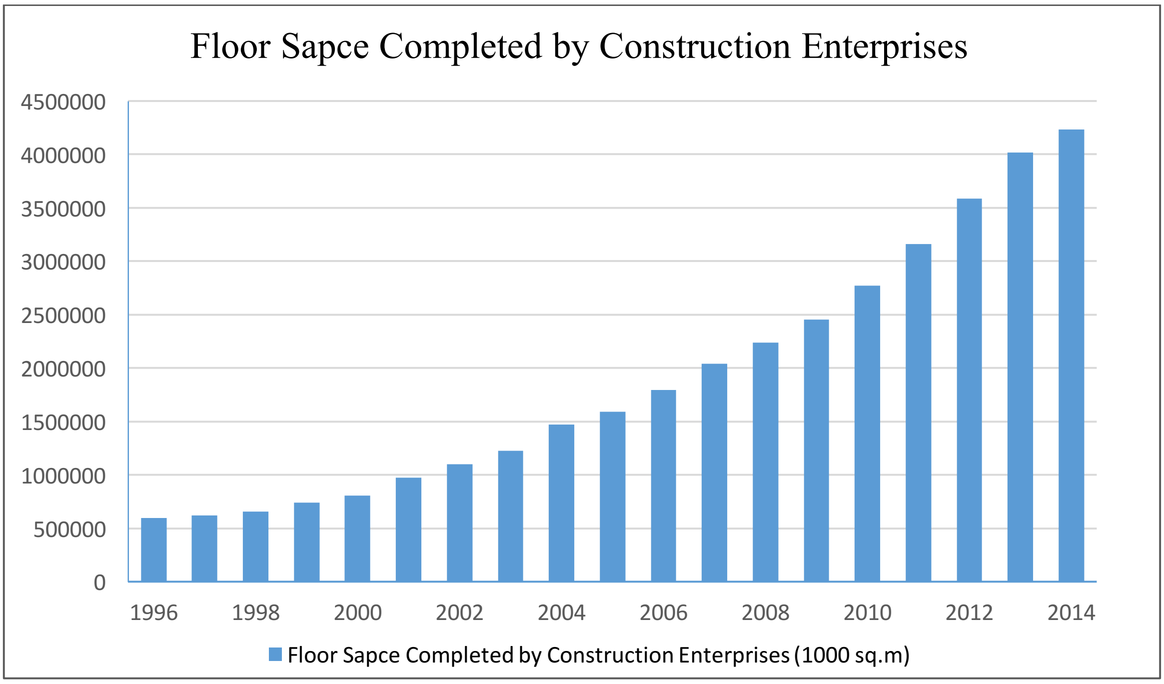
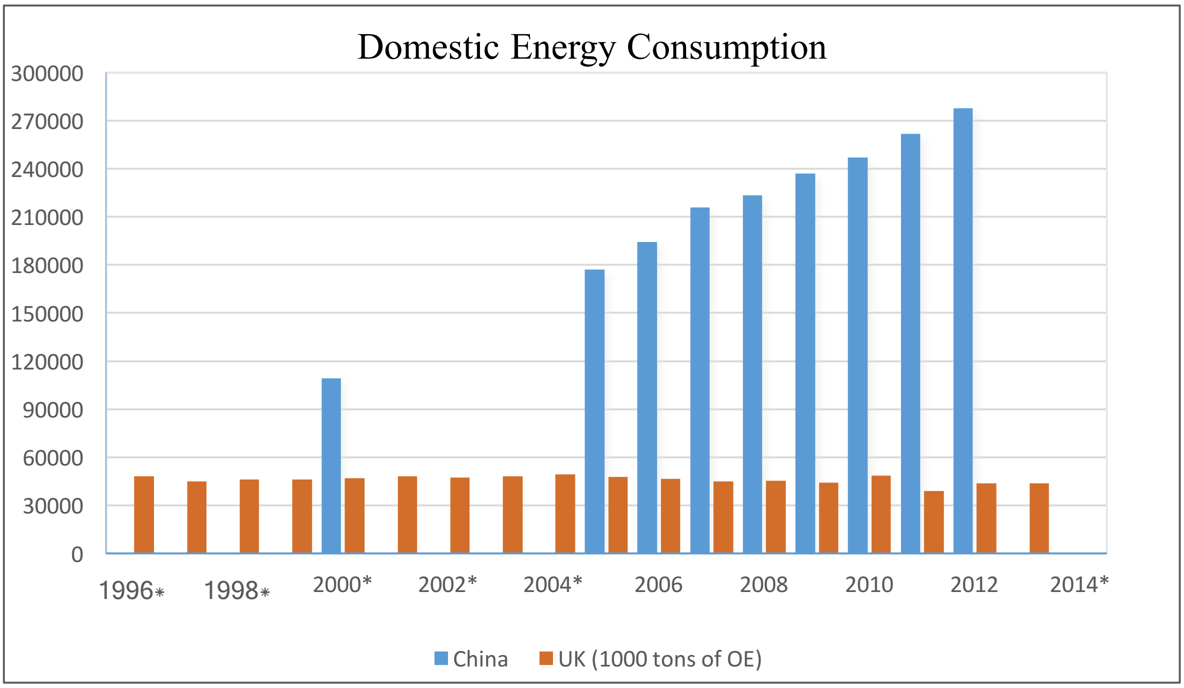


Figure 6.2 Floor Space Completed by Construction Enterprises in China 1996-2014 (National Bureau of Statistics of China, 2015)



*there is no record of China's domestic energy consumption for households from 1996 to 1999, 2001 to 2004; the statistics of domestic energy consumption of 2013 and 2014 have not been published by June 2015.

Figure 6.3 Domestic Energy Consumption in China and UK 1996-2014 (National Bureau of Statistics of China, 2015; World Bank, 2015)

6.1.2 Climate

Climate conditions are the most important factors influencing building energy consumption (Shui and Li, 2012). The climate of China is extremely diverse since tremendous differences in longitude, latitude and altitude. China has five climate zones, including Temperate, Hot Summer Warm Winter (HSWW), Hot Summer Cold Winter (HSCW), Cold, and Severe Cold. As Figure 6.4 and Table 6.1 shows, the increasing energy demand for heating in Temperate, HSCW, Cold, and Severe Cold Zones. The increasing energy demand for cooling in Temperate, HSWW, and HSCW Zones during hot months. In contrast, the climate of the UK is influenced by the latitude and the Atlantic Ocean. As Figure 6.5 and Table 6.1 shows, the hardiness zones relevant to Britain and Ireland are from 7 to 10. This means space heating is the predominant use but space cooling is not required for comfort in the UK's buildings.

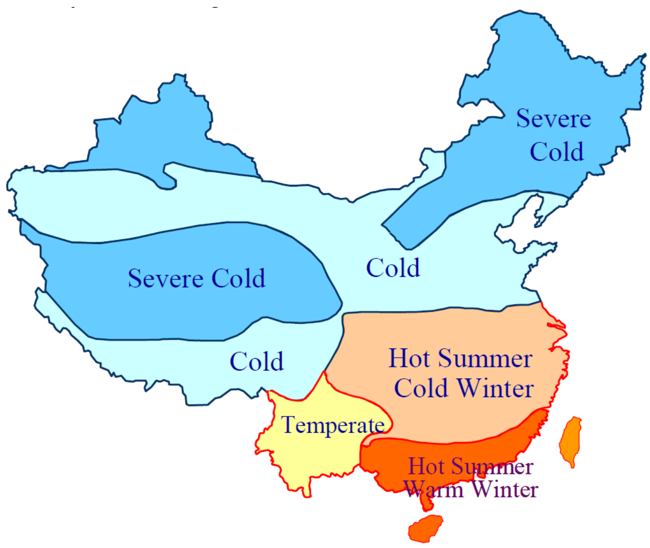


Figure 6.4 Climate Zones of China (Huang and Deringer, 2007)

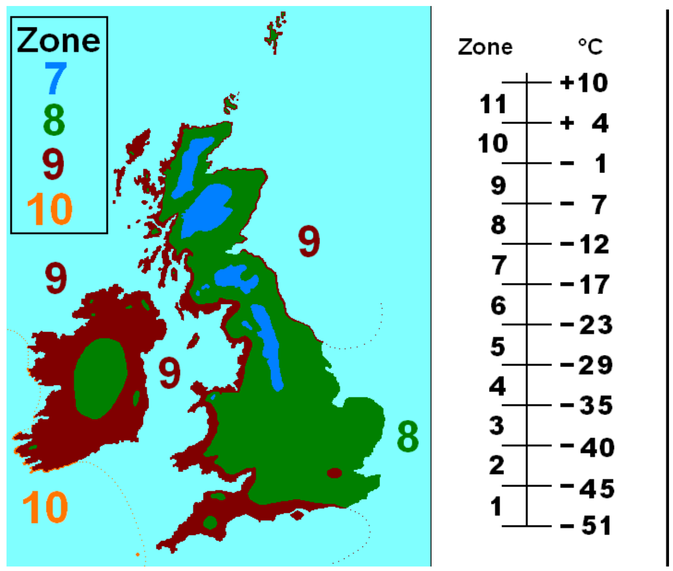


Figure 6.5 Hardiness Zones of the British Isles (Trebrown.com, 1990)

Table 6.1 Mean Temperatures in China and UK

China			UK		
	Mean Temperature			Mean Temperature	
	Coldest Month	Hottest Month		Coldest Month	Hottest Month
Temperate	0°C – 13°C	18°C – 25°C	England	1.1°C – 7.2°C	9.5°C – 20.9°C
HSWW	> 10°C	25°C – 29°C	Scotland	-0.2°C – 5.7°C	7.2°C – 16.9°C

HSCW	0°C – 10°C	25°C – 30°C	Wales	1.1°C – 7.4°C	8.6°C – 19.1°C
Cold	-10°C – 0°C		Northern Ireland	1.2°C – 7.5°C	8.3°C – 18.4°C
Severe Cold	≤-10°C				

Source from Met Office 2001; Huang and Deringer, 2007

6.1.3 Comparative timeline of energy and building regulations

Both China and the UK have developed and deployed an array of policies to improve building energy efficiency and reduce building energy use, as shown in Table 6.2. UK began to introduce the first limits on the amount of heat transfer of new houses within the Building Regulations (1965), and the limits were tightened in 1976's, 1985's, 1990's, 1995's and 2002's version. The Energy Policy of the United Kingdom (2003) articulated direction for more energy efficient building construction. Hence, a significant tightening of building energy efficiency requirements within the Building Regulations 2006. China began to study and conduct building energy efficiency issues since 1980s, it issued the Energy Conservation Design Standard for Civil Building (1986) was the first design standard for residential building to propose the target of energy saving. China used pilot projects to promote new energy-saving buildings in 1990, and began to put in place the authorities to promote building energy efficiency through building energy codes. Changes in 2006, both China and the UK have focused on the application of renewable energy in building energy efficiency, the promotion of green building, the implementation of building energy codes, and the improvement of the existing systems, including technical support systems, administrative system and regulatory system (see Table 6.2).

Table 6.2 Building Energy Efficiency Policy Development in China and UK

Years	**Policies**		**Activities**	
	China	UK	China	UK
1960s		Building Regulations (1965)		It introduced limits on the Thermal Conductivity (the amount of energy that could be lost) in new houses.
1970s		Building Regulations (1976)		Limits on the Thermal Conductivity in new houses were tightened, replaced 1965's version.
1980s	Energy Conservation Design Standard for Civil Building (Heating of Residential Building) (1986)	Building Regulations (1985)	China issued design standard for residential buildings, which proposed energy efficiency (30% off based on building energy use of typical building in the 1980s) (Yang et al, 2011).	Limits on the Thermal Conductivity in new houses were tightened, replaced 1976's version.
	Options on Speeding up the Innovation of Wall Materials and Promotion of Energy Efficient Buildings (1988)		China carried out pilot projects in tow cities.	
1990s	Options on Speeding up the Innovation of Wall Materials and Promotion of Energy Efficient Buildings (1988)	Building Regulations (1990)	Pilot projects were scaled up to eight provinces/ municipalities in 1992.	Limits on the Thermal Conductivity in new houses were tightened, replaced 1985's version.
	Energy Conservation Design Standard for Thermal Engineering and	Building Regulations (1995)	China issued design standard for public buildings, which proposed energy efficiency.	Limits on the Thermal Conductivity in new houses were

	Air Adjustment in Tourist Hotel Building (1993)			tightened, replaced 1990's version.
	The 9th Five Year Plan(1993)	Home Energy Conservation Act (1995)	China's first time to develop and implement policies of building energy efficiency.	Local authorities are required to consider measures to provide free advice on and improve the residential dwelling energy efficiency.
	Energy Conservation Design Standard for Civil Building (Heating of Residential Building) (1995)	Standard Assessment Procedure for Energy Rating of Dwellings (SAP, 1995)	The revised standard increased energy efficiency target (50% off based on building energy use of typical building in the 1980s) (Yang, et al, 2011).	It was the method system for measuring the energy rating of residential dwellings.
	Energy Conservation Law (1997)	Standard Assessment Procedure for Energy Rating of Dwellings (SAP, 1998)		
	Provisions on the Administration of Energy Conservation for Civil Buildings (1999)		China issued regulations for providing specific responsibilities of related stakeholders, including approval, design, construction, inspection, final acceptance and property management of construction projects (Shui and Li, 2012).	
2000s	Design Standards for Energy Efficiency of Residential Buildings in the Hot Summer Cold Winter Region (2001)	Standard Assessment Procedure for Energy Rating of Dwellings (SAP, 2001)		

	Design Standards for Energy Efficiency of Residential Buildings in the Hot Summer Warm Winter Region (2003)	EcoHomes (Pre-2002)	China issued design standards of new residential building energy efficiency in HSWW zones (50% off based on building energy use of typical building in the 1980s).	It was a rating scheme for dwellings related to building energy efficiency.
	Opinions on the Guide for the Pilot Reform Work of Heat Supply Systems in Cities and Towns (2003)	Building Regulations (2002)	This regulation stated requirements of 'implementation of consumption-based tariffs and billings systems, and promotion of energy saving, including heating supply and demand' (Shui and Li, 2012, p.21).	Limits on the Thermal Conductivity in new houses were tightened, replaced 1995's version.
	Design Standard for Energy Efficiency of Public Buildings (2005)	Energy policy of the United Kingdom (2003)	The revised standard increased energy efficiency target (50% off based on building energy use of typical building in the 1980s).	The scope of energy policy is to ensure dwellings are affordably and adequately heated.
	The issuance of the Renewable Energy Law (2005)	EcoHomes (2003)	It was the legal support for the application of renewable energy in building energy efficiency.	
	National Building energy efficiency inspection	Standard Assessment Procedure for Energy Rating of Dwellings (SAP, 2005)		
	Provisions on the Administration of Energy Conservation for Civil Buildings (2006)	EcoHomes (2005)		
	Evaluation Standard for Green Buildings (2006)	Dwelling Emission Rate (2005)		
	Energy Conservation Law (2007)	EcoHomes (2006)		

	Code for Acceptance of Energy Efficient Building Construction (2007)	Code for sustainable Homes (2006)	It dealt with acceptance of construction quality in building energy efficiency.	It is a national standard for use in design and construction to improve building energy efficiency, is an environmental assessment method for rating and certifying the performance of new homes.
	The System of Statistical Reporting on the Energy Consumption of Civil Buildings (2007)	Building Regulations (2006)		Limits on the Thermal Conductivity in new houses were tightened, replaced 2002's version.
	Notice on Distribution of Comprehensive Working Scheme of Energy Conservation and Emission Reduction (2007)	Zero-carbon Standards (2006)		All new housing should be built to zero-carbon standards from 2016.
	The issuance of the Regulations of Energy Conservation in Civil Buildings and Regulation of Energy Conservation of Public Organisations (2008)	Low Carbon Building Programme(LCBP,2006)	It detailed guidance related to building energy efficiency.	It offered grants subject to energy conservation.
	Standards for Energy Efficiency Inspection of Residential Buildings (2009)	Energy Performance Certification (EPC Certificate, 2007)		It is introduced to promote the improvement of residential dwelling energy efficiency.
	Standards for Energy Efficiency Inspection of Public Buildings (2009)	Display Energy Certificate (2008)		It is introduced to promote the improvement of public building energy efficiency.

		Standard Assessment Procedure for Energy Rating of Dwellings (SAP, 2009)		
2010s	Design Standards for Energy Efficiency of Residential Buildings in Hot Summer Cold Winter Regions (2010)	Renewable Heat Incentive (2011)	China issued design standards of new residential building energy efficiency in HSCW zones (65% off based on building energy use of typical building in the 1980s).	It is introduced to replace LCBP (2006), offers grants subject to energy conservation.
	Design Standards for Energy Efficiency of Residential Buildings in Severe Cold and Cold Regions (2010)	Standard Assessment Procedure for Energy Rating of Dwellings (SAP, 2011)	China issued design standards of new residential building energy efficiency in Severe Cold and Cold zones (65% off based on building energy use of typical building in the 1980s).	
	Comprehensive Working Scheme for Energy Conservation and Emissions Reduction in the 12th Five Year Plan (2011)	The Green Deal (2012)		It provides low interest loan for improvements of energy efficiency.
	Evaluation Standard for Green Buildings (2014)		It provided more specific cities to assess green buildings, replaced 2006's version.	

6.2 A comparison on standards, regulations, and policies

In China, the scale of building development is unprecedented (Shui and Li, 2012), according to China Intelligent Building Industry Market Outlook and Investment Strategy Planning Analysis Report (2013-2017), the energy consumed by building account for about 1/3 of China's total energy consumption, which has a significant impact on greenhouse gas emissions. In contrast, buildings accounted for about 43% of all the UK's carbon emissions in 2009 (GOV.UK, 2012). The environment can be damaged by buildings and other development through inefficient energy use. To reduce energy consumption and carbon emission from buildings, the implementation of building planning policies is needed to protect and improve both built and natural environment in China and the UK.

In China, a range of comprehensive building energy codes for new buildings are established, including design standards covering residential and public buildings in China as well as the construction processes, including design, construction and acceptance. The design standards for buildings differ by climate zones, such as the Cold and Server Cold Zones, Hot Summer and Cold Winter Zones and Hot Summer and Warm Winter Zones. The Building Energy Efficiency Labelling and Evaluation was released in 2006 and promoted in 2009 by the Ministry of Housing and Urban-Rural Development. In addition, the standards of green buildings have been established, and are evaluated by the Green Building Labelling in terms of building design (assessed by Green Building Design Evaluation Labelling) and building operation (Green Building Evaluation Labelling).

In parallel with the development and implementation of the new standards and regulations, China tries to improve energy efficiency of existing buildings, including:

- Heat reform- reducing energy waste and reforming heating pricing system by market mechanisms;
- Residential buildings- building retrofit to enhance energy efficiency;
- Public buildings- collection of energy consumption data, energy audits and energy consumption information disclosure;
- Financial support- financial support for residential retrofit projects;
- Application of renewable energy in buildings- geothermal heat pumps, solar water heating, building integrated photovoltaic and photovoltaic power generation;
- Rural buildings energy consumption- encouraging use fossil fuels and reducing use of biomass.

In contrast, in the UK, the policies included in the National Planning Policy Framework explain how to protect the environment and reduce carbon emission. The Code for sustainable Homes is introduced to provide a national standard for designing and building greenhouses. Moreover, the aggregate working parties also provide technical assistance to the mineral planning authorities, local governments and the Secretary of State for Communities with the tree preservation order is released by the UK government to conserve energy. As a state of EU, the UK must follow the Energy Performance of Building Directive that requires three dimensions, including (GOV.UK, 2012):

- Energy Performance Certificate is necessary for all properties when rent, sold or built;
- Display Energy Certificate must be displayed for larger public buildings;
- All air-conditioning system must be inspected by the Energy Assessor if it is over 12Kw.

Furthermore, various practices are implemented in the UK to reduce carbon emissions, including (GOV.UK, 2012):

- More user-friendly and informative Energy Performance Certificates;
- Green deal is introduced to encourage people to improve energy efficiency of their homes;
- Zero Carbon is required for all new dwellings from 2016;
- Zero Carbon is considered to other buildings from 2019;
- Local planning authorities ensure new developments are energy efficient.

In comparison, both China and the UK have developed building energy efficiency codes for new residential and public buildings. According to China Building Energy Efficiency Development Report (2011), China's building energy efficiency codes in three major climate zones consist of design, construction, acceptance, operations and retrofit, and the specific contents include:

- Residential Buildings
    1) Cold Zones-design standards include heating and ventilation, thermal insulation and building envelop;
    2) Hot Summer and Cold Winter Zones- design standards include air conditioning and ventilation systems, heating, thermal insulation and building envelop;
    3) Hot Summer and Warm Winter Zones-design standards include air conditioning and ventilation system, shading and thermal energy for roofs and walls;

- Public Buildings- design standards include air conditioning and ventilation system, thermal insulation and building envelop;
- Acceptance- code for acceptance includes monitoring and control, lighting and power distribution, piping networks, air conditioning and ventilation system, roofs, walls, floors, and windows and doors.

China is to cut energy use for residential building in Cold and Server Cold Zones, Hot Summer and Cold Winter Zones and Hot Summer and Warm Winter Zones by 65%, 50% and 50%, respectively and the saving target for public building is 50% in 2012less compared with the building energy consumption in the 1980s.

In contrast, according to Energy White Paper (2003), The UK'S energy target for new buildings is to cut by 20% in 2006, by 60% by 2050, and by 80% by2100. Many standards related to building efficiency are released by the UK government. According to Building Regulation (2015) of UK, and China Building Energy Efficiency Development Report (2011), a comparison is made between China and UK for the design standards setup for improving building energy efficiencies:

Table 6.3 A Comparison of Design Standards Established for Building Energy Efficiency between China and UK.

	China				U.K.	
	Residential buildings			Public buildings	Dwellings	Other buildings
	Cold and Severe Cold Zones	Hot Summer and Cold Winter Zones	Hot Summer and Warm Winter Zones			
Renewable energy	Yes	Yes	No	No	Yes	Yes
Electrical power	No	No	No	No	No	Yes
Air conditioning and ventilation system	Yes	Yes	Yes	Yes	Yes	Yes
Trade-offs and building component performance approach	Yes	Yes	Yes	Yes	Yes	Yes
Lighting	No	No	No	No*	Yes	Yes

Building envelop	Yes	Yes	Yes	Yes	Yes	Yes
Service hot water and pumping	No	No	No	No	Yes	Yes

'*' energy efficient lighting standards are not included in the building design energy efficiency standards but are included in the lighting standard.

Inspection and supervision are significant factors in enforcing building energy codes. The existing systems of inspection and supervision in China and the UK benefit from regulatory support. Furthermore, improving energy efficiency in the UK is enforced by Energy Performance Certificate and Display Energy Certificate that are inspected by an Energy Assessor. However, Energy Performance Certificate is criticised by professional bodies for their inaccuracy (Snell, 2010). In contrast, the current system of inspection and supervision in China is inspected by the Ministry of Housing and Urban-Rural Development. A comparison is made between China and UK for inspection and supervision in Table 6.4.

Table 6.4 A Comparison for inspection and Supervision of Building Energy Efficiency between China and UK

	Inspected by	Enhanced by
China	Ministry of Housing and Urban-Rural Development	
UK	Energy Assessor	Energy Performance Certificate, Display Energy Certificate

Both China and the UK have applied general strategies to promote buildings energy efficiency across their countries, such as China's Code for Green Buildings and Code for Sustainable Homes in the UK. Specifically, according to Assessment Standard for Green Building (2014), the green building assessment system consists of 7 indexes as listed in Table 6.5.

In contrast, Code for Sustainable Homes is for certifying and rating the performance of new homes in the UK based on 8 criteria as shown in Table 6.5.

It is enforced by Building Research Establishment Environmental Assessment Methodology (BREEAM), UK, that the standard applied to building and location, is the most widely used method of assessing, rating and certifying the building sustainability with versions for refurbishment projects, exiting buildings, new buildings and large developments. The Code for Green Building in China, Code for Sustainable Homes in UK and related assessment systems are the national and/or organisational standards for use in the design and construction buildings to encourage continuous improvement of building energy efficiency. The comparison shows that both countries have developed assessment systems and standards for rating and certifying the building sustainability, however, China has not got an official body who enforces the application of these standards while UK has BREEAM who ensures the building energy consumptions are compliant with the standards.

Table 6.5 A Comparison for Assessment of Green Building/ Sustainable Building between China and UK

	China	UK
Assessment Standards	Assessment Standard for Green Building	Code for Sustainable Homes
Assessment Factors	• Land saving and outdoor environment • Energy saving and energy utilization • Water saving and water resource utilization • Material saving and material resource utilisation • Indoor environment quality • Construction management • Operation management	• Energy and carbon emissions • Materials • Waste • Health and well-being • Ecology • Management • Pollution • Surface water run-off • Water
Enforced by		Building Research Establishment Environmental Assessment Methodology (BREEAM)

6.3 Challenges and potential solutions through benchmarking exercises

Under the construction green SCM framework, the Chinese construction green SCM is benchmarked against the British construction green SCM, and the key competencies within green SCM are compared in Table 6.8. The benchmarking analysis reveals that the green SCM in British construction sector is more cooperative with customers and/ or suppliers for environmental objectives to encourage environmental improvement. Based on this premise, challenges in the Chinese construction green SCM are identified. The potential solutions that are verified by the British construction green SCM during operational lifecycle are recommended.

6.3.1 Existing green SCM practices in British construction sector

The green SCM practices in British construction sector are drawn from the Case studies 3 and 4 in Chapter 5.

- <u>Environmental Management</u>

Environmental implications of green SCM practices are considered by senior management, mid-level management, project team, design team and BREEAM assessor who are committed to and supports environmental practices. Close communication with project team, facade engineers, building engineers, architects, BREEAM assessor and building users to develop the design that can deliver operational carbon savings. Management is based on the effective use of resources that are monitored to improve energy efficiency and reduce carbon emission on the regular basis.

Green construction process is also developed to reduce environmental and occupational safety expenses, including:

  - 3Rs: 3Rs during construction: 1) reduce indirect materials; 2) recycle excess inventory and materials; 3) promote reuse of parts.
  - Energy efficient technology: eco-design considers potential returnable construction components and building maintenance.

- <u>Green Procurement</u>

The green procurement policy requires the procurement team to consider material efficiency, waste to be produced and cost. Suppliers should meet various environmental requirements and can supply environmental friendly materials continually. Green procurement activities including:

  - Green Supplier selection: 1) an external body verifies information submitted by suppliers who implement 3Rs (reducing, recycling and reusing) and obtain green certificate achievements; 2) second-tier suppliers' environmental assessment.

- ISO 14000: the construction company sources more environmentally friendly materials from suppliers and/or second-tier suppliers that are certified by ISO14000 or other environmental directives;
- Environmental requirement: building materials, components and equipment should be with environmental quality standards or passing the audit process following building regulations.
- Green procurement process: paperless order.

- Green Distribution and Reverse Logistics

Green distribution consists of green packaging and green logistics in this case, both of which are outsourced to require monitoring for environmental performance which includes a number of practices as following:

- Green packaging: 1) standardise and downsize packaging; 2) encourage and adopt recycle packaging methods; 3) innovate 3R's programs.
- Green transportation: 1) give priority to local suppliers; 2) direct delivery; 3) energy effective vehicles is a prime consideration; 4) optimise routing and minimise mileage to be travelled.

The reverse logistics activities are related to the reuse and recycle of its building materials, including:

- 3Rs during construction: 1) reduce indirect materials; 2) recycle excess inventory and materials; 3) promote reuse of parts.
- Waste collection: used parts are inspected, selected and sorted which are shipped to recycle plants;
- Techniques utilization: eco-design considers potential returnable construction components and building maintenance.

- Government Involvement

The UK government acts as an enabler and instructor in green SCM practices, has deployed an array of policies to reduce building energy consumption and improve building energy efficiency, and articulates direction for building energy efficiency within the Energy Policy of the UK (2003), tightens the requirements of energy efficiency within the Building Regulation (2006) and promotes the improvements of public building energy efficiency within Display Energy Certificate (2008).

6.3.2 Existing green SCM practices in Chinese construction sector

Existing green SCM practices in Chinese construction sector are benchmarked against the practices in British construction sector.

- Internal Environmental Management

Senior managers put forward the green SCM practices of setting up green image of the company and integrating CSR policy into its business model. Using advanced technologies and practices in constructing green buildings to reduce waste reduction, enhance indoor environmental quality, and improve materials efficiency, water efficiency and energy efficiency. Certifications by ISO9001 and ISO14001 to meet the requirements of customers, minimize negative impacts on the environment, and comply with regulatory and statutory environmental requirements. Implemented cleaner production practices by closely cooperating with research institutes.

Green manufacturing and construction processes are developed to achieve production efficiency, reduce environmental and occupational safety expenses, lower raw material costs, reduce waste of materials, water and energy, including:

  - 3Rs: reduce, reuse and recycle materials such as aluminium, nickel, magnesium, silicon, hydrogen nitrate, sulphuric acid, coal and water;
  - Energy efficient technology: 1) design product for using fewer resources, 2) improve equipment uptime, 3) increase product life span leading to higher productivity and efficiency, 4) reduce energy consumption, 5) Life Cycle Assessment (LCA);
  - Hazardous substance control: 1) quality control and recheck before processing, 2) rinse parts with using reuse water instead of chemicals.

<u>Gaps and recommended practices</u>

Senior management in Chinese companies put forward green SCM practices of integrating CSR policy and setting up green image. The mid-level management, project teams and design teams are committed to and supports environmental practices. The environmental management process lacks cooperation with customers for eco-design and green production. Therefore, Chinese companies can cooperate with their customers to design products or buildings with customers' special considerations for the environmental impacts of the products or buildings during the whole lifecycle.

- Green procurement

o Collecting the environmental information and sets up the database on environmental situations of the materials and components related to suppliers.

  - o Green supplier selection: 1) selecting suppliers who meet environmental requirements and control hazardous resources responsibly, 2) an external body verifies information submitted by suppliers who implement 3Rs (reducing, recycling and reusing) and obtain green certificate achievements.
  - o ISO 14000: prioritising suppliers who acquire ISO 14000 international environmental management certification or other environmental directives;
  - o Environmental requirement: purchasing materials or parts that meet environmental quality standards or passing the audit process following environment-related regulations.
  - o Green procurement process: 1) paperless order, 2) recycle and reuse paper and plastic box.

<u>Gaps and recommended practices</u>

Chinese companies collect environmental information and set up database on environmental situations related to their suppliers. Suppliers should meet the environmental requirements, acquire ISO 14000 certification or other environmental directives. However, these company lack of auditing suppliers' inner environmental management and second-tier suppliers' environmental assessment. Therefore, Chinese company can employ environmental auditors as a third-party certification conducts the environmental management audit within suppliers' organisations to assess biodiversity, emissions and discharge, construction and refurbishment, water, energy, waste management and transport. Companies should priority purchase parts or materials from suppliers whose suppliers have environmental directives such as ISO 14000.

- Green Distribution and Reverse Logistics

Green distribution increase space utilisation and lower materials usage, is outsourced to achieve Just-in-time (JIT) production and require monitoring for economic and environmental performance. The findings in green distribution practices include:

- Green Packaging: 1) promote reuse and recycle package, 2) encourage and adopt returnable packaging methods, 3) standardize packaging, 4) downsizing packaging; 5) innovate 3R's programs.
- Green transportation: 1) distribute products together rather than in smaller batches, 2) optimise routing and minimise mileage to be travelled; 3) give priority to local suppliers when ordering building materials, components and equipment; 4） direct delivery; 5) energy effective vehicles is a prime consideration.

Practices of reverse logistics include waste collection, disposal and reprocessing that are related to 3Rs.

- Waste collection: initially inspects, selects and sorts the used parts which are shipped to recycle plants;
- Waste treatment: Water waste and solid waste are treated by final Treatment/ landfill companies;
- Recycle Plants: recycling plant collects used parts from customers or manufacturing plants, and recycle metals.
- Final treatment: the construction waste is treated by landfill companies who have industrial waste treatment and disposal systems.
- 3Rs during construction: 1) reduce indirect materials; 2) recycle excess inventory and materials; 3) promote reuse of parts.
- Techniques utilization: eco-design considers potential returnable construction components.

<u>Gaps and recommended practices</u>

The practices of Chinese green distribution involve green packaging and green transportation that increase space utilisation and lower materials usage and the amount of handling required. However, Chinese companies lack cooperation with customers and/or suppliers during green distribution process. Therefore, Companies would be possible to cooperate with customers and/or suppliers during distribution process to increase energy efficiency and reduce carbon emission.

- Government Involvement

Chinese government's involvement facilitates maximising the performance improvement resulted from the implemented green SCM practices, organises workshops and offer guidelines and framework for implementing green SCM practices and suggest measures to be taken, provide leadership by increasing awareness of environmental protection, offer financial incentives and helps companies developing and implementing energy saving schemes that aim to reduce the energy consumption in the company. Chinese companies benefited from the technical assistances offered by government, such as workshops for energy conservations and minimising wastes generated from production. The government encourages and fosters collaborations between research institutions and companies to maximise the use of end-of-life products, including potential for materials retrieval, energy recovery, high recyclability, re-manufacturability and reusability.

Gaps and recommended practices

Chinese government has released an array of regulations and standards; however, it lacks enforceable environmental laws and regulations provide guidelines and directives for the industry. Therefore, Chinese government should introduce enforceable environmental laws and regulations to provide guidelines and directives and enhance public awareness of carbon emission.

Table 6.6 Construction Green SCM Framework

Key competencies	**Descriptions**
Internal environmental management	Its activities involve commitment from mid-level and senior level management, inter-department cooperation, environmental compliance and auditing system, and improvement of manufacturing process.
Green procurement	Its activities involve cooperation with suppliers, environmental requirements, and ISO14000 certification.
Green distribution and reverse logistics	Its activities involve environment friendly transportation, excess inventory and materials,

	used material and scrap, and technology utilization.
Government involvement	Its activities involve government coordination, infrastructure, assistance from government, and knowledge popularization.

Table 6.7 Similarities between the Chinese and British Construction Green SCM

Key competencies	**Chinese and British Construction Green SCM**
Internal management	Both contain green production practices, including 3Rs (reduce, reuse and recycle materials), energy efficient technologies, using renewable resources, and hazardous substance control.
Green procurement	Practices adopted include green supplier selection, environmental requirements and ISO 14000 certificate.
Green distribution and reverse logistics	Green packaging and green transportation are involved in green distribution practices; waste treatment and waste collection are included in reverse logistics practices.
Government involvement	Both countries' authorities offer grants and provide technical guidelines and assistances; building energy efficiency has become national infrastructure priority in both countries.

Table 6.8 Benchmarking Chinese green construction SCM against British green construction SCM

Key competencies	**Gaps identified in Chinese Green construction SCM**	**Best practices Recommended**
Internal Environmental management	Lack of cooperation with customers for eco-design and green production	Companies cooperate with their customers to design products or buildings with customers' special considerations for the environmental impacts of the products or buildings during the whole lifecycle.
Green Procurement	Lack of auditing suppliers' inner environmental management; Lack of second-tier suppliers' environmental assessment;	Environmental auditors employed by third-party certification conduct the environmental management audits within suppliers' organisations to

		assess biodiversity, emissions and discharge, construction and refurbishment, water, energy, waste management and transport. Companies priority purchase parts or materials from suppliers whose suppliers have ISO 14000 certificate.
Green Distribution and Reverse Logistics	Lack of cooperation with customers and/or suppliers for green packaging and transportation	Companies cooperate with customers and/or suppliers for green distribution, including green packaging and green transportation.
Government Involvement	Lack of enforceable environmental laws and regulations	Introduce enforceable environmental laws and regulations.

Chapter 7 Major Findings and Discussions

The major findings of this study and the consequent discussions for Chinese green SCM can be summarised as follows.

Green SCM pressures/ drivers have driven green SCM practice adoption in Chinese enterprises to gain “benefits” ranging from straightforward cost reduction to facilitating the development of cooperative relationship with suppliers, and even encouraging a life-cycle, holistic approach in managerial decision making. Green SCM practice has a positive influence on reducing energy consumption, which is one of the indicators for improved environmental performance. The resulted environmental performance is overall better than the economic performance; green SCM practices have more influence on positive environmental performance than on positive economic performance. Adoption and implementation of green SCM practices in Chinese construction industry may take longer time as the environmental and economic benefits are not perceived to be significant. Chinese companies are facing several challenges that will affect companies in construction industry to implement green SCM practices.

- Green SCM pressures/ drivers

Findings from the empirical analysis and the case studies indicate that companies in Chinese construction industry are facing multiple green SCM pressures from regulatory bodies, customers and internal policies, and are also reacting with various green SCM practices. Sample of Chinese enterprises in construction industry has a broad set of green SCM pressures, drivers and influences on green SCM practices (shown in Table 4.7, 4.18). Each item such as regulation, market and internal factors listed in the set has been viewed as having some level of importance on investigated items (means over 4.00).

Market is regarded as the most important or effective pressure in adopting or implementing green SCM practice. The factors of regulation and internal factors are also considered as important pressures and drivers. Regulatory pressures on medium sized enterprises are most significant, especially environmental regulation and national (domestic) regulation in China (as summarised in Table 4.10). It may be seen that the influences of green SCM pressures and drivers are very strong, and managers who work in Chinese medium sized enterprises are quite aware of these pressures and drivers to address environmental issues and adopt green SCM practices. Results reveal that Chinese enterprises have experienced strong pressures from the relevant environmental regulations, but they may face the similar and very early pressure or drivers from market and the internal motivations.

The empirical analysis based on the survey shows that there is positive relationship between the increasing environmental pressures and adoption of green SCM practices across the Chinese construction industry. The green SCM pressures/ drivers have significantly driven adoption of green SCM practices in these Chinese enterprises to achieve "benefits". The alleged benefits of implementing green SCM practices are boarder than straightforward cost reduction, and include facilitating the development of cooperative relationship with suppliers, and even encouraging a life-cycle, holistic approach in managerial decision making. In addition, results also indicated that industry sector did not have significant relationship with green SCM practices, but firm size seems to have a significant negative relationship with government involvement measures (Shown in Table 4.18). It seems that in this sample of Chinese enterprises, the resources offered by government to smaller sized companies play an important role in influencing adoption of green SCM practices.

Green SCM pressures faced by SJAC and SJSC feel are similar as those faced by other surveyed companies in Chinese construction supply chain. Both case studies of SJAC and SJSC indicate that green SCM drivers/ pressures on Chinese construction industry, such as environmental laws and regulations, customer environmental awareness and company's internal motivation, encourage the implementation of green SCM practices, including green procurement, internal environmental management, green distribution and reverse logistics, and government involvement (Shown in Figure 5.1, 5.2). The building material manufacturer, SJAC considers and implements the green SCM practices, including internal environmental management, green procurement (including the green supplier selection, ISO 14000 certification and environmental requirement), green distribution and reverse logistics (including green packaging, green transportation, waste collection and treatment, and recycle plants), and government involvement that are required by environmental laws and regulations, pressures from market and its corporate social responsibility (Shown in Figure 5.1). The Chinese real estate developer SJSC has implemented internal environmental management, green procurement (including the green suppliers selection, ISO 14000 certification, environmental requirement and green procurement process), green distribution and reverse logistics (including green packaging, green transportation, final treatment, 3Rs during construction and techniques utilisation) and government involvement that are required by the environmental laws and regulations, pressures from market; and driven by financial support from local government and its corporate social responsibility (Shown in Figure 5.2).

Positive relationships between green SCM pressures and green SCM adoption have been observed in empirical analysis, but case studies of SJAC and SJSC explicitly verify that a causal relationship exists between green SCM pressures and implementations, which is similar as the findings from Zhu, Sarkis and Lai (2007). As summarised in Zhu, Sarkis and Lai (2007), these multi-faceted green SCM pressures faced by the Chinese construction SC 'will eventually make the entities in the SC adopt baseline level of many green SCM practices'. Furthermore, compared with Zhu, Sarkis and Geng (2005) where 'a clear lag between pressures/drivers and practices of green SCM in Chinese manufacturing enterprises was identified'. This research reveals that Chinese construction industry has experienced both green SCM pressures/drivers and green SCM practices, and that the green SCM pressures/drivers have significantly driven green SCM practices in these Chinese enterprises.

- Green SCM practices

The results show that the Chinese companies in construction sector have implemented the green SCM practices by raising the awareness of green SCM practices, offering education on green SCM practice, and in cooperating environmental programs. The practices of internal environmental management, green procurement, green distribution and reverse logistics, and government involvement have received commitment from senior level management, middle level management, inter-departmental cooperation, supplier, partners and government. Furthermore, the government involvement has become an important green SCM practice in Chinese construction industry such as the government coordination, infrastructure, assistance from government and knowledge popularization.

The government has imposed the pressure/ drivers to adopt green SCM practices, but the enterprises may react at the different peace to adopt practices of green SCM when responding to the market pressure and internal motivation. Although the government actively involves the adoption of green SCM practices, the practices of green SCM in enterprises may be more significant as the green SCM pressures/ drivers become more mature since most of the enterprises in Chinese construction industry are at the early stage of adopting green SCM practices. The larger sized enterprises may have more competitive advantages in the market.

These results in Chinese enterprises in construction industry are supported by the literature by a number of researchers who have looked at other organisations. The internal environmental management items of middle management support (Carter, Ellram and Kathryn, 1998) and commitment from senior level management (Carter, Kale and Grimn, 2000), Inter-departmental cooperation and improvement of manufacturing process (Zhu and Sarkis, 2004) were tested for their respective impacts on green SCM practices. The middle and top management should be totally committed to ensure the complete environmental excellence due to the support from managers is the necessary driver for the successful implementation and adoption of most activities, programs, technology, and innovations (Carter, Kale and Grimn, 2000). The success of eco-design requires the inter-departmental cooperation among the entire enterprise and other parties in SC (Lenvis and Gretsakis, 2001). The process of production equipped with the environmentally sound technological innovations is most advanced in operational life cycle (Gillett, 1993). The investigation of this research presented a good level of internal environmental management adopting and implementation in Chinese construction industry as the mean value of each items of internal environmental management are all above 4.0 (Shown in Table 4.8).

Most Chinese enterprises are aware of the importance of green procurement (Zhu and Sarkis, 2004) but few have really implemented it due to lack of knowledge and tools (Wu, Zhu and Geng, 2001). However, globalization may increase export for China to developed countries where customers pressure Chinese to self-regulate environmental performance (Christmann and Taylor, 2001). Furthermore, multi-national enterprises have changed from foreign direct investors to multinational operators through global supply networks (Zhu and Sarkis, 2004). More and more Chinese enterprises have improved both environmental and quality performance by adopting green purchasing practices through cooperation with suppliers for environmental objectives and requirements for purchased items (Zhu, Sarkis and Lai, 2007) because they have become suppliers of foreign enterprises. Some Chinese enterprises have begun to implement green SCM on the basis environmental management system such as ISO 14000 certification to achieve environmental objectives (Zhu and Geng, 2003). This research showed that green procurement practice is highlighted with high mean (4.54) among four green SCM practices (Shown in Table 4.8), and can bring slightly direct and better economic and environmental performance (Shown in Table 4.19). Companies in building material sector seem to be more mature in their adoption and implementation of green procurement practice (Shown in Table 4.14).

Empirical results indicate that green distribution and reverse logistics has a slightly positive influence on environmental performance (Shown in Table 4.19). Implementation of green distribution and reverse logistics can result in cost saving such as fees for waste treatment and discharge (Zsidisin and Hendrick, 1998) and decrease of cost for energy consumption (Zhu, Sarkis and Geng, 2005). Green distribution and reverse logistics is helpful to improve environmental performance by minimizing life-cycle environmental impacts and addressing product functionality (Zhu and Sarkis, 2004). The success of reverse logistics is important for green purchasing in German and American enterprises (Zsidisin and Hendrick, 1998). Environmental friendly transportation is an important green SCM practice to reduce energy consumption in Chinese automobile enterprises (Zhu, Sarkis and Lai, 2007). Discussion with managers in Chinese enterprises found that the interest in green distribution and reverse logistics is mainly because of regulatory pressures. This survey also demonstrated that adoption of green distribution and reverse logistics is highlighted with high mean (4.64) among four green SCM practices.

Governments have become involved in green SCM initiatives as environmental regulations shift emphasis from pollution control to the life cycle of the products. The government has set up a foundation to conduct research that can generate advanced technology for enterprises in Thai cane sugar industry. In addition, the Thai government also plays an important role by setting up and specific quotas for production for both national and international markets (Wei, Li and Lu, 2004). In China, government changed over from a resource subsidy to levy taxes for some resources such as natural gas and coal (Zhu and Cote, 2002), and enhanced its waste management policy and recycling systems (Zhu, et al., 2007). The investigation indicated that the Chinese government has effectively involved in green SCM with high mean value (4.60), but the enterprises may react at the different peace to adopt practices of green SCM when responding to government involvement.

- Green SCM performance

Green SCM practice has a positive influence on reducing energy consumption, which is one of the indicators for improved environmental performance. The resulted environmental performance is overall better than the economic performance; green SCM practices have more influence on positive environmental performance than on positive economic performance. Therefore, adopting and implementing green SCM practices in Chinese construction industry may take longer time as the environmental and economic benefits are not perceived to be significant. However, the alleged benefits of implementing green SCM practices are broader than straightforward cost reduction, and include facilitating the development of cooperative relationship with suppliers, and even encouraging a life-cycle, holistic approach in managerial decision making. In addition, results showed that industry sector did not have significant relationships with any of the performance measures, but firm size seem to have a significant positive relationship with economic performance measures. It seems that in the sample of organisations in Chinese construction industry, extra resource available for larger sized firms play a role in contributing to the economic performance measures.

The perceived performance implications of green SCM were major issues the researcher targeted in this survey. The results suggest that a lag may exist between adoptions of green SCM and performance in Chinese enterprises. Both green SCM performance are below 4.00 (relatively important) but above 3.00 (to some degree), with 3.36 for environmental performance and 3.20 for economic performance (Shown in Table 4.9).

In terms of green SCM practices adoption and implementation, the two case companies are comparatively more active and advanced compared with other surveyed companies in the empirical analysis. Case studies on SJAC and SJSC indicate that successful implementation of green SCM practices bring economic and environmental benefits, as evidence in reduced pollution, reduced energy consumption, reduced air emission, expanded market share, avoidance of regulatory penalties and increased revenues (Shown in Table 5.1-5.9). Case study on SJAC indicates that SCM practices have improved environmental and economic performance including reduced consumption of hazardous materials, reduced consumption of water and coal fuel, increased consumption of clean energy, reduced air emission, reduced solid and water waste and enlarged market share (Shown in Table 5.1-5.3). SJSC has gained environmental benefits such improvement of energy efficiency of buildings and economic benefits like avoidance of regulatory penalties, more competitive productions, green image, awards, expanded market share and increased revenues (Shown in Table 5.4-5.9). Environmental liability and responsibility costs, resource costs, waste and toxic substance treatment costs relative to green SCM issues of those companies should be reduced through the more efficient resources use. Therefore, the integrated green SCM could systematically consider all concerns of stakeholders of SJAC and SJSC, including suppliers, producers, partners, customers and communities, and drives toward a common objective of environmental conservation.

In addition, medium and large sized companies have much better economic performance than small ones (Shown in Table 4.12). Empirical results indicate that both environmental and economic performance seem to not have any significant relationships with each factor of green SCM practices (Shown in Table 4.19). In particular, green procurement has slightly direct and positive impacts on environmental performance and economic performance. Green distribution and reverse logistics has a slightly direct and positive influence on environmental performance. It is not surprising that companies in Chinese construction industry have significantly initiated implementing the practices of green SCM as driven by the green SCM pressures/drivers, and extra resources available for larger sized firms play a role in contributing to the economic benefits. However, the practices have been implemented at the early starts and have not resulted in significant improvement in the green SCM performance in Chinese construction industry, both economically and environmentally.

- Challenges and potential solutions for green SCM in Chinese construction industry

Challenges

Through benchmarking exercise, the researcher finds that senior management in Chinese companies put forward green SCM practices of integrating CSR policy and setting up green image. The mid-level management, project teams and design teams are committed to and supports environmental practices. However, the environmental management process lacks cooperation with customers for eco-design and green production. It is necessary for Chinese companies to consider how to improve cooperation strategies and initiatives with their customers. Further, Chinese companies lack auditing suppliers' inner environmental management and second-tier suppliers' environmental assessment. Those companies collect environmental information and set up database on environmental situations related to their suppliers who must meet the environmental requirements, acquire ISO 14000 certification or other environmental directives. Lack of basic auditing suppliers' inner environmental management and second-tier suppliers' environmental assessment is another challenge for Chinese green procurement practices. In addition, Chinese companies lack cooperation with customers and/or suppliers during green distribution process. Chinese companies have adopted and implemented green packaging and green transportation that increase space utilisation and lower materials usage and the amount of handling required. Procedure and process restructuring may require the cooperation with suppliers and customers to build a new business process for green distribution practices. Finally, Chinese government involvement is crucial for green SCM initiatives successfully. The government released an array of regulations and standards but it lacks enforceable environmental laws and regulations provide guidelines and directives for the industry. Such challenge will affect Chinese companies to implement green SCM practices proactively.

Potential solutions

Green SCM practices in Chinese construction industry include four aspects, including internal environmental management, green procurement, green distribution and reverse logistics, and government involvement. Operational life cycle of the organisation is regarded as more tactical set of organisational factors that impact both internal and external SCM (Ninlawan, et al., 2010), that involves five main components, including procurement, production, distribution, reverse logistics and packaging. According to the current situations and challenges, Chinese companies can cooperate with their customers and suppliers to initiate green SCM practices with customers' special considerations for the environmental impacts to overcome challenges during the whole lifecycle.

The procurement decision impacts the green SCM, through the type of purchased materials, or through the selection of vendors (Ghobakhloo, et al., 2013). Procurement department in Chinese companies could decide whether to outsource the components or processes for environmental purposes if outsourcing is to be used. Chinese company can employ environmental auditors as a third-party certification conducts the environmental management audit within suppliers' organisations to assess biodiversity, emissions and discharge, construction and refurbishment, water, energy, waste management and transport. Companies should priority purchase parts or materials from suppliers whose suppliers have environmental directives such as ISO 14000.

The production process impacts the green SC in many ways, including 1) how well the processes are designed for the waste prevention, 2) capabilities to integrate remanufactured or reusable components into the systems, and 3) a capability process to reuse the materials. Since the production is usually the internal focus of an organisation, the process of production becomes the function that enables the advancement and the innovations of the environmentally sound technological process, which allows Chinese government to introduce enforceable environmental laws and regulations to provide guidelines and directives and enhance public awareness of carbon emission.

Operation networks of transportation and distribution are also significant characteristics of operation that can influence the green SC (Ninlawan, et al., 2010). The operation of distribution is most closely tied to the customers' requirements and characteristics. Therefore, involvement of customer in the design and development of distribution system seems to provide the efficient and effective distribution network. Thus, Chinese companies would be possible to cooperate with customers during distribution process to increase energy efficiency and reduce carbon emission.

The reverse logistics primarily focus on the return of reusable and recyclable materials and products into the forward SC from the environmental perspectives. The typical activities in a reverse logistics are 1) collection, 2) separation, 3) densification, 4) transitional processing, 5) delivery, and 6) integration (Pohlen and Farris, 1992). To have a fully operational reverse logistics system, Chinese companies not only need a network for the collection process, but also a number of the processes and systems.

Packaging has the strong relationships with other functions of life cycle of operation. The key features of packaging in terms of materials, shape and size can influence distribution (Sarkis, 2003). Along with rearranged from loading patterns, better packaging can 1) reduce the amount of handling required, 2) increase utilisation of space in the trailer and warehouse, and 3) reduce materials usage. Therefore, adoption of returnable packaging in Chinese companies requires an effective channel of reserve logistics and a strong relationship with customers and suppliers. The efficiency in packaging directly affects the environment.

Chapter 8 Managerial Implications

This study is an example for improving the environmental performance of Chinese construction industry. It is also a benchmark research in a Chinese scenario against the British environmental practices, which identifies good practices in green SCM adoption. The conclusions of the research help to focus and identify green SCM pressures and are justified by the opinions collected in the interviews with governments and supply chain mangers.

Both China and the UK have been actively promoting building energy efficiency with strong supports from governments, local communities and other organisations. Both countries make great efforts in improving energy use efficiency and reducing carbon emissions by setting up strict building regulations, a series of polices and practical programmes of building energy efficiency. In particular, the demands for air conditioning and ventilation systems, thermal insulation materials, energy efficient lighting and energy efficient walls and windows will grow alongside with the stronger requirements on building energy efficiency in China and the UK (Shown in Table 6.2, 6.3), which could enlarge the market share of building material company such as SJAC. Although there are some limitations in current policies and programmes, both countries have achieved significant progress in improving building energy efficiency and reduction of carbon emissions with strong supports from related stakeholders and appropriate monitoring and oversight by professional bodies and authorities.

The benchmarking exercise also reveals that the green SCM in British construction sector is more comprehensive and effective as the customers and suppliers have more proactive involvement in the green SCM practices. The gaps in internal environmental management, green procurement and green distribution are identified by benchmarking analysis. Communications among British companies, suppliers and customer through implementation of green SCM are richer and diverse than Chinese firms' green SCM. The best green SCM practices, including inner suppliers' environmental management audit, second-tier suppliers' environmental assessment, and cooperation with customers and suppliers for green objectives that adopted by British firms, but not by Chinese companies (Shown in Table 6.8).

To encourage implementation of green SCM practices in the construction SCs in China, efforts must be made to enhance communication with customers, improve collaborations between SC parties, and introduce official bodies who enforce regulations, provide economic incentives, and invest in infrastructure and technology. Success of all these improvement measures depends on the presence of support from the government and investment by the building materials suppliers as well as constructors.

Regulatory stakeholders are the important environmental stakeholder groups who have the ability to influence governments to set regulations that are imposed on companies internally for driving environmental activities. (Henriques and Sadorisky, 1999; Del and Jaunquera, 2003). This research indicates that to successfully implement and expand green SCM practices in Chinese construction SC, the central government is recommended enforcing environmental laws and regulations and providing guidelines and directives for the industry. Next, organisational stakeholders such as customers who have enhanced the environmental awareness and prefer the 'green' products can have the direct financial impact on the organisation (Chan and Lau, 2001). Thus, government should enhance public awareness of carbon emission and energy uses from unsustainable and sustainable buildings, and launch the campaign on environmental protection and conservation through education and promotion. In addition, Eco-design is a help and emerging tool to improvement environmental performance by minimising life-cycle environmental impacts and addressing product functionality (Zhu and Sarkis, 2004). The government should also take the initiative to invest in research and development of new, clean and sustainable building materials, encourage and award innovative and sustainable building designs, and financially sponsor or award companies that invest in sustainable buildings.

Observing a national-wide policy that has to yet to be developed, local governments should provide financial aids to building materials manufacturers or construction companies to help implement green SCM practices and to facilitate collaboration among them and customers. At the same time, Chinese government can help companies to identify useful benchmarking reference to disseminate experiences and replicate the path for successful green SCM implementation in the construction industry. As Holt, Anthony and Viney (2001) suggested, government strategy could include a range of scope from financial and technical support to indirect encouragement and infrastructure development, such as undertaking the energy efficiency best practice campaign to provide free advice and technical support, bringing awareness of green SCM practices through manuals and guidebooks, developing the best practices of green supply chain, and other government driven initiatives. One of findings in this research is that large enterprises with more resources and stronger capabilities also should take the lead to invest in sustainable design and construction so as to set examples for smaller manufacturers to follow. Successful green construction SC requires the whole-hearted participation of all the parties in the SC, including suppliers, manufacturers, distributors, and end-users. The government, however, should play a central role of facilitator and coordinator.

The weakness of external cooperation has impeded on the improvement of Chinese companies' green SCM practices. Benchmarking practices in Chinese companies against those in British companies, suppliers and customers are recommended to be involved in eco-design and green packaging and transportation. The success of eco-design and external green SCM requires the cross-functional cooperation among the enterprise and the external cooperation with other partners in the whole supply chain (Lenvis and Gretsakis, 2001; Zhu and Sarkis, 2004). Companies can cooperate with their suppliers and customers to design products or buildings and adopt green packaging and transportation methods with special considerations for the environmental impacts of the products or buildings during the whole lifecycle. Chinese companies can also exert the green SCM pressures to their suppliers (including first-tier and second tier suppliers) to encourage them to achieve environmental certification. ISO 14000 certification and other proactive environmental tools can be introduced and treated as one of the key aspects for supplier selection. Monitoring and auditing supplier's environmental performance is important for green procurement. Chinese companies can depute analysing suppliers' data to a third-party organisation to check whether suppliers meet environmental requirements.

The research value of measuring the relationships between pressures/ drivers and practice adoption, and ultimate performance improvement is clear, but practical managerial value can only be realised when long-term improvements and practice adoption decisions are made, which can be supported by strict and complete legislative rules and policies.

Chapter 9 Conclusion and Further Research

There are increasing concerns regarding the adverse environmental consequences of construction work undertaken, and the carbon emissions from more and more skyscraper buildings. To rectify the damage on the environment, a significant economic investment has to be made. To address these concerns, green SCM becomes a new frontier in various industrial sectors and are investigated in this research limited to Chinese construction sector, which constitutes approximately 28% of China's carbon emissions. The green SCM in Chinese construction sector requires the involvement of the entire supply chain, from materials manufacturers, through wholesaler/ logistics providers, to construction companies, to investors and finally to customers.

Literature has shown that green SCM becomes an important model for organisations to lower environmental risks and achieve profit objectives while improving ecological efficiency. Organisations in Chinese construction supply chain have struggled to improve their economic and environmental performance, although they have made some progress in adoption of green SCM practices.

- With the requirements of regulatory bodies, customers and internal driven, environmental awareness have been increased and green SCM practices have emerged as systematic approaches for the construction industry in China. Regulations and internal factors can be considered as important green SCM drivers and pressures. The existence of regulatory pressures improves adoption of internal environmental management, green procurement, green distribution and reverse logistics, and government involvement. In particular, medium and large sized Chinese companies face higher regulatory pressures than small firms. Internal driven encourages adoption of internal environmental management, green distribution and reverse logistics. Correspondingly, companies in Chinese construction industry facing higher market pressures tend to better government involvement practices.
- The adoption rates of green SCM practices shown in investigation is high that indicates green SCM is not a new concept in Chinese construction industry. Companies have begun to change their focus from single plant improvement to the entire supply chain. Most of the companies have recognised the importance of green SCM and tried to put it into practices, including internal environmental management, green procurement, green distribution and reverse logistics. Correspondingly, China's local governments

provide necessary infrastructure, coordination, assistance and skills. In particular, Chinese companies in construction sector seem to be more matured in their adoption of green procurement practices than other companies in building material sector.

- Green SCM practices and their relationships to green SCM performance (environmental and economic performance) are evaluated. It shows that there are a number of minor relationships among green SCM practices and performance. However, there is not any significant relationship between green SCM practices and performance since most of the enterprises just initiate implementing green SCM practices. Additionally, medium and large sized companies in Chinese construction industry have better economic performance than small sized companies.
- In case studies, evidence of direct relationships is observed in pioneering enterprises such as Shandong Jinxiang Aluminium Corporation and Shandong Jinsheng Corporation. The causal relationships between green SCM drivers/ pressures, practices and performance become more evident. Therefore, the green SCM performance may be more obvious as the adoption of green SCM practices become more matured and widespread in Chinese construction industry. It is expected that these causal relationships probably exist in the broader industry and its supply chains.
- Similarities exist between Chinese and British construction sectors, in terms of implementation of 3Rs, energy efficient technology, hazardous substance control, green supplier selection, environmental requirement, green procurement process, green packaging, green transportation, waste collection, waste treatment, and strong supports from regulatory bodies. However, this research shows that green SCM in British construction sector is more comprehensive and effective. The key cause for the differences is customers and suppliers in British cases have more proactive involvement in green SCM practices. The communication among British companies, customers and suppliers through implementation of green SCM are richer and diverse than Chinese firms' green SCM. To improve green SCM practices in Chinese construction sector, this research benchmarks the two Chinese case companies against two British cases, and generates a profile of recommendations based on the best practices. Improvement can be made within green SCM practices to proactively implement inner suppliers' environmental management audit, second-tier suppliers' environmental assessment, and cooperation with customers and suppliers for green objectives, including eco-design, green production, green packaging and green transportation.

Comparing with Zhu, Sarkis and Lai's (2007) study in which the sample only included a convenience sample of companies and respondents were not randomly selected, this research adopts convenience sampling enhanced by quota sampling and systematic random sampling procedures. However, this study is not without its limitations in arriving at these overall results and this research can await further studies considering these limitations. First, samples used in this research were extracted from a government list, which may not comprehensively present all companies in Chinese construction industry. Next, the design of each questionnaire of this research was only answered by one respondent, which may create grounds for bias. In addition, the relationship between green SCM practices and performance may be moderated by other organisational practices such as just-in-time practices and quality management programmes that may help influence green SCM performance implications of the practices. Finally, only economic and environmental performance is considered influenced by green SCM practices. Thus, further research would adopt larger random samples and serve quality management programs and just-in-time practices as moderators to investigate the green SCM. Further research can also include investigation of other possible organisational performance, including shareholder return, product market performance, and financial performance.

While studies investigating environmental management exist for specific stand-alone industries, we contribute to the body of knowledge by further investigating green SCM practices in a quickly developed sector in a developing economy. The research of this study is original in that no existing piece of work has investigate environmental sustainability issues facing the construction or real estate development SC in China. There has not been an attempt to critically describe relationships between green SCM pressures/ drivers, practices and performance; determine industry or sector differences in embracing green SCM pressures/drivers, practices and performance; nor explored and identified gaps existing between green SCM in Chinese construction industry and British construction industry through benchmarking exercise.

The findings from this research provide managerial and theoretical insights for construction industry in China to improve their green SCM practice adoption and implementation. This thesis makes a significant contribution to the field of knowledge by offering contributions towards a methodological position. This has been done by developing a new standpoint for examination of the green SCM issues. The construction industry has become the pillar industry of China's economy. Supply side structural reforms for construction industry have reached a consensus at the national level in China, which is important to mention in the 13 FYP for many times. This research is an in-depth study of China's construction industry facing issues and challenges in green SCM, and combined with the success in the British cases to put forward reasonable suggestions of green SCM in China. In a sense, this research provides a basic theoretical and practical reference to the supply side structural reforms for Chinese construction industry. The findings also have potential implications on government policy or regulation, which is needed to support green SCM practice implementation in industries.

Overall, it has been a challenge to monitor and measure the economic performances, and link pressures/drivers with green SCM practices. The relationships among pressures/ drivers, practices and performance are analysed by obtaining inputs from interviewees, and by gaining deeper insights from the two case studies. This research is one of the few studies that has considered the sustainable development practices and implications of the world's largest emerging economy in the construction industry and may provide a precious portray of the situation in China.

References

Aerts, W., Cormier, D., and Magnan, M. (2006), "Intra-industry imitation in corporate environmental reporting: an international perspective", Journal of Accounting and Public Policy, Vol. 25(3), pp.299-331.

Aitken, J. Childerhouse, P. and Towill, D. (2003), "The impact of product life cycle on supply chain strategy", International Journal of Production Economics, Vol.85, pp.127-140.

Alvaredz, G. M. J., Jimenez, J. B. and Lorente, J. C. (2001), "An analysis of environmental management, organizational context and performance of Spanish hotels", Omega, Vol. 29 (6), pp. 457- 471.

Andersen, B., Fagerhaug, T., Randmal, S., Schuldmaier, J. and Prenniger, J. (1999), "Benchmarking supply chain management: finding best practices", Journal of Business and industrial Marketing, Vol.14 (5/6), pp.378-389.

Armstrong, J. S. (2012), "Illusions in regression analysis", International Journal of Forecasting, Vol.28 (3), p.689.

Askarany, D., Yazdifar. H., and Sakary, S. (2010), "Supply chain management, activity- based costing and organizational factors", International Journal of Production Economics Vol.127 (2), pp. 238– 248.

Aspan, H. (2000), "Running in nonconcentric circles: why environmental management isn't being integrated into business management", Environmental Quality Management, Vol. 9 (4), pp. 9-75

Ayres, R. U. (1978). "Resources, environment, and economics: applications of the materials/ energy balance principle", John Wiley and Sons, New York, NY.

Ayres, R. U. and Kneese, A.V. (1969), "Production, consumption, and externalities", The American Economic Review, Vol. 59 (3), pp.282– 297.

Babbie, E. R. (2009), "The practice of social research", 12th edition, Wadsworth Publish, pp.436-440.

Bai, C. and Sarkis, J. (2010), "Green supplier development: analytical evaluation using rough set theory", Journal of Cleaner Production, Vol.18 (12), pp. 1200–1210.

Ball, A. and Craig, R. (2010), “Using neo-institutionalism to advance social and environmental accounting”, Critical Perspectives on Accounting, Vol.21(4), pp.283-293.

Barnes, J. H. (1982), “Recycling: a problem in reverse logistics”, Journal of Macro- marketing, Vol. 2 (2), pp.31–37.

Bernard, H. R. (2011), “Research methods in anthropology: qualitative and quantitative approaches”, Altamira Press, UK.

Bentz, D., Garboczi, E. J., Haecker, C. J. and Jensen, O. M. (1999), “ Effects of cement particle sized distribution on performance properties of Portland cement-based materials”, Cement and Concrete Research, Vol.29 (10), pp.1663-1671.

Bergh, J. (2002), “Do social movements matter to organizations? An institutional perspective on corporate responses to the contemporary environmental movement”, PhD thesis, The Pennsylvania State University, State College, PA.

Bhote, K. (1989), “Strategic Supply Management”, AMACOM, New York.

Blackstone, A. (2015), “Principles of sociological inquiry: qualitative and quantitative methods”, [Online] available at http://catalog.flatworldknowledge.com/bookhub/reader/3585?e=blackstone_1.0-ch02_s03#blackstone_1.0-ch00about, accessed on 20/12/2015.

Bland, J. M and Altman, D. G. (1996), “Statistics notes: measurement error”, [Online] available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2351401/pdf/bmj00548-0038.pdf, accessed on 29 June, 2016.

Bowen, E. F, Cousins, P. D., Lamming, C. R. and Faruk, A. C. (2001), “The role of supply management capabilities in green supply”, Production and Operations management. Vol.10 (2), pp.174-189.

Carter, C.R. (2000), “Ethical issues in international buyer-supplier relationships: a dyadic examination”, Journal of Operations Management, Vol. 18 (2), pp. 191-208.

Carter, R.C. and Carter, J.R. (1998), “Inter-organizational determinants of environmental purchasing: initial evidence from the consumer products industry”, Decision Sciences, Vol.29, pp.28–38.

Carter, C. R., Kale, R., and Grimm, C. M. (2000), “Environmental purchasing and firm performance: an empirical investigation”, Transportation Research Part E: Logistics and Transportation Review, Vol. 36 (3), pp.219–228.

Carter. C.R., Ellram. L.M. and Kathryn, L.M. (1998), “Environmental purchasing: benchmarking our German counterparts”, International Journal of Purchasing and Materials Management, Vol. 34 (4), pp. 28-38.

CBI (1994), “Firm foundations: confederation of British industry”, Centre point, London.

Chan, R.Y.K. and Lau, L.B.Y. (2001), “Explaining green purchasing behaviour: a cross-cultural study on American and Chinese consumers”, Journal of International Consumer Marketing, Vol. 14 (2/3), pp. 9-41.

Chavez, R. Yu, W., Feng, M., and Wiengarten, F. (2016), “The effect of customer-centric green supply chain management on operational performance and customer satisfaction”, View Issue of TOC, Vol. 25 (3), pp. 205-220.

China Daily (2011), “China to adopt auto emission standard equal to Euro III in 2008”, [Online] available at http://www.chinadaily.com.cn/english/doc/2004-07/07/content_346332.htm, accessed on 01/09/2014.

Chien, M. K and Shih, L. H. (2007), “An empirical study of the implementation of green supply chain management practices in the electrical and electronic industry and their relation to organisational performances”, International Journal of Environmental Science and Technology, Vol.4 (3), pp.383-397.

Chmutina, K. (2010), “Building energy consumption and its regulations in China”, China Policy Institute, University of Nottingham.

Christmann, P. and Taylor, G. (2001), “Globalization and the environment: determinants of firm self-regulation in China”, Journal of International Business Studies, Vol. 32 (3), pp. 439-58.

Creswell, J.W. (1994), “Research design: qualitative and quantitative approaches”, London: Groom Helm.

Cruz, J. M. and Matsypura, D. (2009), “Supply chain networks with corporate social responsibility through integrated environmental decision-making”, International Journal of Production Research, Vol. 47 (3), pp.621– 648.

Cooper, D. R and Schindler, P. S (2008), "Business research Methods", McGraw-Hill Higer Education, London.

Cohen, M. D. and Manion, L. (1980), "Research methods in education", London: Groom Helm.

De Giovanni, P. and Vinzi, V. E. (2012), "Covariance versus component-based estimations of performance in green supply chain management", International Journal of Production Economics, Vol. 907-916.

Dean, J. W. and Snell, S.A. (1991), "Integrated manufacturing and job design: moderating effects of organisational inertia", Business Strategic Environment, Vol.13, pp.209-222.

Del, B. J. and Junquera, B. (2003), "Influence of the perception of the external environmental pressures on obtaining the ISO 14001 standard in Spanish industrial companies", International Journal of Production Research, Vol. 41(2), pp.337e48.

Denzin, N. K. and Lincoln, Y. S. (2005), "The sage handbook of qualitative research", Thousand Oaks, CA: Sage.

DiMaggio, P.J. and Powell, W.W. (1983), "The iron cage revisited: institutional isomorphism and collective rationality in organizational fields", American Sociology Review., Vol.48, pp.147–160.

Dodgson, M. (2000), "Management of technology", Routedge, London

Drumwright, M. E. (1994), "Socially responsible organisational buying: environmental concern as a non-economic buying criterion", Journal of Marketing, Vol.58, pp.1–19.

Draft, R. L. (1995), "Organisation theory and design 5th Ed", West Publishing Company, New York.

Dyer, J. H. and Singh, H. (1998), "The relations view: co-operative strategy and sources of inter-organizational competitive advantage", Academy of Management Review, Vol. 23, pp. 660- 679.

Easterby-Smith, M., Golden-Biddle, K. and Locke, K. (2008), "Working with pluralism: Determining quality in qualitative research", Organizational Research Methods, Vol.11, pp.419–429.

Ecovativedesign (2015), "Official website", [Online] available at http://www.ecovativedesign.com/, accessed on 01/12/2015.

Erkman, S. (1997), "Industrial ecology: an historical view", Journal of Cleaner Production Vol.5 (1/2), pp.1–10.

Fabrigar, L.R., Wegener, D.T., MacMallum, R.C. and Strahan, E.J. (1999), "Evaluating the use of exploratory factor analysis in psychological research", Psychological Methods, Vol. 4(3), pp.272-299.

Feller, M. (1950), "Introduction to probability theory and its applications", John Wiley& Son, US.

Field, A. (2009), "Discovering statistics using SPSS, 3rd Edition", London.

Finch, J. F. and West, S.G. (1997), "The investigation of personality structure: Statistical models", Journal of Research in Personality, Vol.31 (4), pp.439-485.

Finelli, G. M. (2011), "From the dinner table to the boardroom: the effects of nepotism on family business", PhD dissertation, College of Arts and Sciences of American University.

Foo, M. F. (1997), "Environmental auditing in the construction industry", Unpublished B.Sc. (Building) Dissertation, National University of Singapore.

Frosch, R. (1994), "Industrial ecology: minimizing the impact of industrial waste", Physics Today, Vol. 47 (11), pp. 63- 68.

Frosch, R. A. and Gallopoulos, N. E. (1989), "Strategies for manufacturing. Scientific American", Vol. 9, pp.144–152.

Galaskiewicz, J. and Wasserman, S. (1989), "Mimetic processes within an inter-organisational field: an empirical test", Administrative Science Quarterly, Vol.34 (3), pp.454-479.

Geffen, C. and Rothenberg, S. (2000), "Sustainable development across firm boundaries: the critical role of suppliers in environmental innovation", International Journal of Operations and Production Management, Vol. 20(2), pp. 166- 186.

Geng, Y., Haight, M. and Zhu, Q. (2007), "Empirical analysis of eco-industrial development in China", Sustainable Development, Vol. 15, pp. 121 – 133.

Geyer, R. and Jackson, T. (2004), "Supply loops and their constraints: the industrial ecology of recycling and reuse", California Management Review, Vol. 46(2), pp. 55-73.

Ghobakhloo, M. Tang, S. H., Zulkifli, N. and Ariffin, M. K. (2013), “An integrated framework of green supply chain management implementation”, International Journal of Innovation, Management and Technology, Vol. 4 (1), pp. 86-89.

Gillett, J. (1993), “Ensuring suppliers’ environmental performance”, Purchasing and Supply Management, pp.28-30.

Glessner, L. and Gillis, D. (2012), “The knowledge product lifecycle and the strategic dashboard”, Continuing Higher Education Review, Vol. 76, pp. 100-111.

Goddard, W. and Melville, S. (2004), “Research methodology: an introduction”, Second edition, Blackwell Publishing.

Gonzalez, B. J. and Gonzalez, B. O. (2006), “The role of stakeholder pressure and managerial values in the implementation of environmental logistics practices”, International Journal of Production Research, Vol. 44(7), pp.1353–1370.

GOV.UK (2012), “Energy efficiency in buildings”, [Online] available at https://www.gov.uk/government/policies/improving-the-energy-efficiency-of-buildings-and-using-planning-to-protect-the-environment, accessed on 27/04/2015.

Gunther, E. and Scheibe, L. (2006), “The hurdle analysis: a self-evaluation tool for municipalities to identify, analyse and overcome hurdles to green procurement”, Corporate Social Responsibility and Environmental Management, Vol.13 (2), pp.61–77.

Hall, J. (2000), “Environmental supply chain dynamics”, Journal of Cleaner Production 2000, Vol.8 (6), pp.206-225.

Hall, J. (2001), “Environmental supply-chain innovation”, Greener Management International, Vol.35, pp. 105-119.

Hamel, G. and Prahalad, C. K. (1989), “Strategic intent”, Harvard Business Review, Vol. 67, pp. 63-76.

Handfield, R. B and Nichols, E. L. (1999), “Introduction to supply chain management”, New Brunswick NJ: Prentice-Hall.

Handfield, R., Sroufe, R., and Walton, S. (2005), “Integrating environmental management and supply chain strategies”, Business Strategy and the Environment, Vol.14 (1), pp.1-19.

Hanna, M. D. and Newman, W. R. (1996), "Operations and the environment: an expanded focus for TQM", International Journal of Quality and Reliability Management, Vol. 12 (6), pp. 38-53.

Hanna, M. D., Newman, W. R. and Johnson, P. (2000), "Linking operational and environmental improvement through employee involvement", International Journal of Operations and Production Management, Vol. 20 (2), pp. 148-165.

Hansmann, K.W. and Claudia, K. (2001), "Environmental management policies", in Sarkis, J. "Green Manufacturing and Operations: from Design to Delivery and Back", Greenleaf Publishing, Sheffield, pp. 192-204.

He, Y. and Su, Y. (2011), " Chinese construction waste cycling suffered serious environmental pollution growing pains", [Online] available at http://www.chinanews.com/gn/2011/10-14/3389008.shtml, accessed on 25/03/2015.

Henriques, I., and Sadorsky, P. (1999), "The relationship between environmental commitment and managerial perceptions of stakeholder importance", Academy of Management Journal Vol.42 (1), p.87e

Hervani, A. A., Helms, M. M, and Sarkis, J. (2005), "Performance measurement for green supply chain management", Benchmarking: An International Journal, Vol. 12 (4), pp. 330-353.

Hick, S. (2000), "Morals make the money", Austrian CPA, Vol.70, pp. 72-73.

Hippel, E. (1988), "The Source of Innovation", Oxford University Press, Oxford.

Holt, D., Anthony, S. Viney, H. (2001), "Supporting environmental management system in domestic small and medium-sized firms", Vol.35, pp.29-49.

Huang, J. and Deringer, J. (2007), "Energy efficiency building standards in China", [Online] available at http://www.asiabusinesscouncil.org/docs/BEE/papers/BEE_Policy_China.pdf, accessed on 19/06/2015.

Hunt, C.B, Auster, E.R. (1990). Proactive environmental management: avoiding the toxic trap. MIT Sloan Manage. Rev., Vol.31 (2), pp.7-18.

Hutchison, J. (1998), "Integrating environmental criteria into purchasing decision: value added?" in Russel, T., "Green Purchasing: Opportunities and Innovations", Greenleaf Publishing, Sheffield, pp. 164- 178.

Iacono, J., Brown, A., and Holtham, C. (2009), “Research Methods- a case example of participant observation”, The Electronic Journal of Business Research Methods, Vol.7 (1), pp.39-46.

IBM (2014), “Factor Analysis: KMO and Bartlett’s Test”, [Online] available at http://pic.dhe.ibm.com/infocenter/spssstat/v22r0m0/index.jsp?topic=%2Fcom.ibm.spss.statistics.cs%2Fspss%2Ftutorials%2Ffac_telco_kmo_01.htm, accessed on 02/09/2014.

Jelinski, L.W., Graedel, T. E., Laudise, W. D., McCall, D.W., and Patel, K. N. (1992), “Industrial ecology: concepts and approaches”, Proceedings of the National Academy of Sciences, Vol. 89, pp.793–797.

Johansson, G. (2006), “Incorporating environmental concern in product development: a study of project characteristics”, Management of Environmental Quality: An International Journal, Vol.17 (4), pp. 421-436.

Jorgensen, M.S., Jorgensen, U., Hendriksen, K., Hirsbak, S. Thomsen, H. H. and Thorsen, N. (2010), “Environmental management in Danish transnational textile product chains”, Management Research Review, Vol. 33 (4), pp. 357-379.

Kagan, R. A., Gunningham, N. and Thornton, D. (2003), “Explaining corporate environmental performance: How does regulation matter”, Law Society Review, Vol.37, pp.51–90.

Kemp, R., and L. Soete (1992) “The Greening of Technological Progress: An Evolutionary Perspective”, *Futures*, Vol.24 (5), pp. 437-445.

Kilbourne, W

Klassen, R. D. and McLaughlin, C. P. (1996), “The impact of environmental management on firm performance”, Management Science, Vol .42 (8), pp. 1199-1214.

Kovacs, G. (2004), “Framing demand network for sustainability”, Progress in Industrial Ecology: an International Journal, Vol.1 (4), pp.397–410.

Lai, K.H. and Cheng, T.C.E. (2009), “Just-in-Time Logistics”, Gower Publishing, England.

LaMarca, N. (2011), “The Likert Scale: advantages and disadvantages”, [Online] available at https://psyc450.wordpress.com/2011/12/05/the-likert-scale-advantages-and-disadvantages/, accessed on 02/09/2014.

Lamming R, Hampson J.(1996), “ The environment as a supply chain management issue”, British Journal of Management, Vol.7, pp.45-62.

Lee, S. (2008), “Drivers for the participation of small and medium-sized suppliers in green supply chain initiatives”, Supply Chain Management: An International Journal, Vol.13 (3), pp.185-198.

Lewis, H. and Gretsakis, J. (2001), “Design Environment: a global guide to designing greener goods”, Greenleaf Publishing, Sheffield.

Linton, J. D., Klassen, R. and Jayaraman, V. (2007), “Sustainable supply chains: an introduction”, Journal of Operations Management, Vol.25 (6), pp.1075–1082.

Linyi Environmental Protection Agency (2012), “Environmental Assessment Report on SJAC”, Linyi.

Liu, Z. (2015), “China’s carbon emission report 2015”, Sustainability Science Program and Energy Technology Innovation Policy research group, Belfer Centre Discussion Paper.

Lo, C. and Leung, S. (2000), “Environmental agency and public opinion in Guangzhou: the limits of a popular approach to environmental governance”, The China Quarterly, Vol.163, pp. 677–704.

Lytle, M. H. (2007), “The gentle subversive: Rachel Carson, silent spring, and the rise of the environmental movement”, Oxford University Press, New York.

Madaan, J. and Wadhwa, S. (2007), “Flexible process planning approaches for sustainable decisions in reverse logistics system”, Global Journal of Flexible Systems Management, Vol.8 (4), pp.1-8.

Marien, E. J. (1998), “Reverse logistics as competitive strategy”, Supply Chain Management Review, Vol.34 (2), PP.43-52.

Maria, D. Lopez-Gamero, J. F., Molina-Azorin, E. C. (2009), “The relationship between environmental variables and firm performance: competitive advantage and firm resources as mediator variables”, Journal of Environmental Management, Vol. 90, pp.3110-3121.

Mason, C. H. and Perreault, W. D. (1991), “Collinearity, power, and interpretation of multiple regression analysis”, Journal of Marketing Research, Vol.28 (3), pp.268-280.

Melnyk, S. A., Sroufe, R. P. and Calatone, R. (2002), “Assessing the impact of environmental management systems on corporate and environmental performance”, Journal of Operations Management, Vol. 21(2), pp. 329-351.

MIIT(2011), “ Notice on printing and distributing standards for medium and small sized enterprises (2011-300)” (Chinese Version).

Min, H. and Galle, W. P. (1997), “Green purchasing strategies: trends and implications”, The Journal of Supply Chain Management, Vol. 33 (3), pp.10–17.

Ministry of Foreign Trade and Economic Cooperation of PRC (MFTECO) (2003), “Foreign countries put forward different environmental requirements for fabrics and dyes of clothes”, [Online] available at http://www.mofcom.gov.cn, accessed on 23/10/2013.

Murphy, P. R. and Poist, R. F. (2000), “Green logistics strategies: an analysis of usage patterns”, Transportation Journal, Vol. 40 (2), pp.5– 16.

Murphy, P. R., Poist, R. F. and Braunschweig, C.D. (1994), “Management of environmental issues in logistics: current status and future potential”, Transportation Journal, Vol. 34 (1), pp.48–56.

Nagel, M. H (2000), “Environmental supply-chain management versus green procurement in the scope of a business and leadership the scope of a business and leadership perspective”, IEEE Proceedings of the 2000 IEEE International Symposium, Vol.8/10, pp. 219–224.

Narasimhan, R. and Carter, J. R. (1998), “Environmental Supply Chain Management”, Centre for Advanced Purchasing Studies, Tempe, AZ.

Narasimhan, R. and Schoenherr, T. (2012), “The effects of integrated supply chain management practices and environmental management practices on relative competitive quality advantage”, International Journal of Production Research, Vol. 50 (4), pp. 1185-1201.

News Agency of Xinhua (2001), “How should China do to meet with the challenge of green barriers”, Economy Daily, p. A2.

Ninlawan, C. Seksan, P., Tossapol, K and Pilada, W. (2010), “The Implementation of green supply chain management practices in Electronic industry”, Proceeding of the International MultiConference of Engineers and Computer Scientists, Vol. III, Hong Kong.

North, D. (1990), “Institutions, institutional change and economic performance”, Cambridge, UK: Cambridge University Press.

Nunnally, J. C. (1978), “Psychometric Theory”, McGraw-Hill, New York, NY.

Office for National Statistics (2012), 2011 Census: population estimates for the United Kingdom, [Online] available at http://www.ons.gov.uk/ons/dcp171778_292378.pdf, accessed on 19/06/2015.

Papadopoulos, A. M. and Giama, E. (2007), “Environmental performance evaluation of thermal insulation materials and its impact on the building”, Building and Environment, Vol.42 (5), pp. 2178-2187.

PBL Netherlands Environmental Assessment Agency (2015), “Trends in global carbon emissions 2015 report”, Free press.

Peattie, K. and Ringler, A. (1994), “Management and the environment in the UK and Germany: a comparison”, European Management Journal, Vol.12 (2), pp.216-225.

Pohlen, T. L. and Farris, M. T. (1992), “Reverse logistics in plastics recycling”, International Journal of Physical Distribution and Logistics Management, Vol. 22 (7), pp.35–47.

Puckett, J. and Smith, T. (2002), “Exporting harm: the high-tech trashing of Asia”, The Basel Action Network, Seattle: Silicon Valley Toxics Coalition.

Rao, P. (2002), “Greening the supply chain: a new initiative in South East Asia”, International Journal of Operations and Production Management, Vol. 21 (6), pp. 632-655.

Rao, P. and Holt, D. (2005), “Do green supply chains lead to competitiveness and economic performance? “, International Journal of Operations and Production Management, Vol. 25 (9), pp. 898-916.

Revell, A. (2007), “The ecological modernisation of SME in the UK’s construction industry”, Geofourm, Vol.38, pp.114-126.

Rice, S. (2003), “Commitment to excellence: practical approaches to environmental leadership”, Environmental Quality Management, Vol. 12(4), pp. 9-22.

Richter, L. (2010), “Pros and cons of benchmarking”, [Online] available at http://www.brighthub.com/office/entrepreneurs/articles/82292.aspx, accessed on 28/12 /2015.

Rivera, J. (2004), “Institutional pressures and voluntary environmental behaviour in developing countries: evidence from the Costa Rican hotel industry”, Society & Natural Resources, Vol. 17 (9), pp.779 – 797.

Roy, M.J. and Therin, F. (2008), “Knowledge acquisition and environmental commitment in SMEs”, Corporate Social Responsibility and Environmental Management, Vol.15, pp.249-259.

Sarkis, J. (1995), “Supply chain management and environmentally conscious design and manufacturing”, International Journal of Environmentally Conscious Design and Manufacturing, Vol. 4 (2), pp.43–52.

Sarkis, J. (2001), “Manufacturing’s role in corporate environmental sustainability: concerns for the new millennium”, International Journal of Operations and Production Management, Vol. 21 (5/6), pp. 666- 685.

Sarkis, J. (2003), “A strategic decision making framework for green supply chain management”, Journal of Cleaner Production, Vol. 11(4), pp. 397-409.

Sarkis. J, Zhu. Q and Lai, K. (2011), “An organizational theoretic review of green supply chain management literature”, International Journal of Production Economics, Vol. 130, pp. 1 - 15.

Scott, W. R. (2001), “Institutions and organisations, 2nd Edition”, Thousand Oaks, CA: Sage Publications.

Seuring, S. (2001), “A framework for green supply chain costing: a fashion industry example”, in: Sarkis J, “Green manufacturing and operations: from design to delivery and back”, Greenleaf Publishing; 2001, p. 150–60, Sheffield (UK).

Seuring, S. and Muller, M. (2008), “.From a literature review to a conceptual framework for sustainable supply chain management”, Journal of Cleaner Production, Vol.16 (15), pp.1699–1710.

Shandong Normal University, Shandong Zhonglu Environmental Engineering Assessment Centre and Shandong Chemical Industry Institute (2011), “Environmental impact report on SJAC”, Free Press, Shandong.

Sharma, S. and Vredenburg, H. (1998), “Proactive corporate environmental strategy and the development of competitive valuable organisational capabilities”, Strategic Management Journal, Vol. 19, pp. 729-753.

SJSC (2014), “Annual report of Shandong Jinsheng (Group) Corporation”, Free Press, Linyi.

SJSC (2006-2014), “SJSC energy efficiency of residential buildings assessment reports”, Free Press, Linyi.

Shandong Jinluo Water Waste Treatment Inc (2011), “Water waste assessment report on SJAC”, Free Press, Shandong.

Sharfman, M., Shaft, T. and Anex, R. (2009), "The road to cooperative supply-chain environmental management: trust and uncertainty among proactive firms", Business Strategy and the Environment, Vol.18 (1), pp.1–13.

Shui, B. and Li, J. (2012), "Building energy efficiency policies in China", Free Press, the Global Building Performance Network.

Shultz, C. J. and Holbrook, M. B. (1999), "Marketing and tragedy of the commons: a synthesis, commentary and analysis for action", Journal of Public Policy and Marketing, Vol. 18(2), pp. 218- 229.

Simpson, D. F. and Power, D. J. (2005), "Use the supply relationship to develop lean and green suppliers", Supply Chain Management: An International Journal, Vol. 10 (1), pp. 60-68.

Snell, D. (2010), "Do not waste your energy on eco-certificates", The Telegraph, [Online] available at http://www.telegraph.co.uk/finance/property/advice/propertyclinic/7590776/Dont-waste-your-energy-on-eco-certificates.html, accessed on 27/04/2015.

State Council of P.R. of China (2003), "Official Document of State Council on Promoting Cleaner Production", Free Press.

Stern, M. O., Ayres, R. U. and Saxton, J. C. (1973), "Tax strategies for industrial pollution abatement", IEEE Transactions on Systems Man and Cybernetics, Vol.3 (6), pp.588–603.

Svensson, G. (2001), "Just-in-time: the reincarnation of past theory and practice", Management Decision, Vol.39 (10), pp.866–879.

Szwilski, T. B. (2000), "Using environmental management systems to systematically improve operational performance and environmental protection", International Journal of Surface Mining, Reclamation and Environment, Vol. 14 (3), pp. 183- 191.

Szymankiewicz, J. (1993), "Going green: the logistics dilemma", Logistics Information Management, Vol.6 (3), pp. 36–43.

Trebrown.com (2015), "Plant hardiness zone map of the British Isles", [Online] available at http://www.trebrown.com/hrdzone.html, accessed on 27/04/2015.

Tsai, W. and Hung, S. (2009), "A fuzzy goal programming approach for green supply chain optimisation under activity-based costing and performance evaluation with a value-chain structure", International Journal of Production Research, Vol. 47 (18), pp. 4991-5017.

Vachon, S. and Klassen, R. D. (2006), "Extending green practices across the supply chain: the impact of upstream and downstream integration", International Journal of Operation & Production Management, Vol. 26 (7), pp. 795-821.

Van Hoek, R. (2000), "From reversed logistics to green supply chains", Logistics Solutions Issue, Vol.2, pp.28-33.

Wagner, M., Schaltegger, S. and Wehrmeyer, W. (2001), "The relationship between the environmental and economic performance of firms: what does theory propose and what does empirical evidence tell us?" Greener Management International, Vol. 34, pp. 95-108.

Walker, D. (2008), "Sustainability: Environmental management, transparency and competitive advantage", Journal of Retail and Leisure Property, Vol. 7, pp.119-130.

Walton, S.V, Handfield, R. B, and Melny, S. A. (1998), "The green supply chain: integrating suppliers into environmental management processes", International Journal of Purchasing and Materials Management, Vol.2 (11).

Wei, Y., Li, Q. and Lu, J. (2004), "The visiting report of cane sugar industry in Thailand", Guangxi Light Industry, Vol. 1, pp. 5-10. [In Chinese]

Williams, H., Medhurst, J., and Drew, K. (1993) "Corporate strategies for a sustainable future", In: Fischer K, Schot J, editors." Environmental strategies for industry", Washington, DC: Island Press; 1993.pp. 117-146.

Wilson, J. (2010), "Essentials of business research: a guide to doing your research project", SAGE Publications.

WordPress (2011), "Advantages and disadvantages of quantitative research", [Online] available at http://picardsflute.wordpress.com/2011/01/12/advantages-and-disadvantages-of-quantitative-research/, accessed on 01/11/ 2013.

Wu, H. J. and Dunn, S. C. (1995), "Environmentally responsible logistics systems", International Journal of Physical Distribution and Logistics Management", Vol.25 (2), pp.20-38.

Wyse, S. E. (2011), "What is the difference between qualitative research and quantitative research", [Online] available at http://www.snapsurveys.com/blog/what-is-the-difference-between-qualitative-research-and-quantitative-research/, accessed on 20/12/2015.

Xie, Y. and Breen, L. (2014), "Who cares wins? A comparative analysis of household waste medicines and batteries reverse logistics systems", Supply Chain Management: An International Journal, Vol.19 (4), pp.455-474.

Yang, X., Zhang, S., Qi, Y. and Jiang, Y. (2011), Design standards for building energy efficiency and the estimation of the quantity of energy efficiency. Research on Urban Development .Vol.18 (10).

Young, A., and Kielkiewicz-Young., A. (2001), "Sustainable supply network management", Corporate Environmental Strategy, Vol.8 (3), pp.260–268.

Zaklad, A., McKnight, R., Kosansky, A. and Piermarini, J. (2004), "The social side of the supply chain: align three factors, and hitting the jackpot is a sure bet", Industrial Engineer, Vol. 36(2), pp. 40-44.

Zhu, Q. and Cote, R. P. (2002), "Green supply chain management in China: how and why", The Fifth International Eco-city Conference, China.

Zhu, Q. and Cote, R. P. (2004), "Integrating green supply chain management into an embryonic eco-industrial development: a case study of the Guitang Group", Journal of Cleaner Production, Vol.12, pp1025 – 1035.

Zhu, Q. and Geng, Y. (2001), "Integrating environmental issues into supplier selection and management: a study of large and medium-sized state-owned enterprises in China", Greener Management International, No. 35, pp. 27-40.

Zhu, Q. and Geng, Y. (2013), "Drivers and barriers of extended supply chain practices for energy saving and emission reduction among Chinese manufacturers", Journal of Cleaner Production, Vol.40, pp. 6 – 12.

Zhu, Q .and Liu, Q. (2010), "Eco-design planning in a Chinese telecommunication network company: benchmarking its parent company", Benchmarking: An International Journal, Vol. 17 (3), pp. 363-377.

Zhu, Q. and Sarkis, J. (2004), "Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises", Journal of Operations Management, Vol. 22(3), pp. 265-289.

Zhu, Q. and Sarkis, J. (2006), “An inter-sectorial comparison of green supply chain management in China: Drivers, and Practices”, Journal of Cleaner Production, Vol.14, pp. 472 – 486.

Zhu, Q. and Sarkis, J. (2007), “The moderating effects of institutional pressures on emergent green supply chain practices and performance”, International Journal of Production Research, Vol.45 (18-19), pp. 4333- 4355.

Zhu. Q, Sarkis. J, and Geng. Y. (2005), “Green supply chain management in China: pressures, practices and performance”, International Journal of Operations and Product Management, Vol.25 (5), pp449 - 468.

Zhu. Q. H., Sarkis, J. and Lai, K. H. (2007), “Green supply chain management: pressures, practices and performance within the Chinese automobile industry”, Journal of Cleaner Production, Vol.15, pp1041-1052.

Zhu, Q., Geng, Y., Fujita, T. and Hashimoto, S. (2010), “Green supply chain management in leading manufactures: case studies in Japanese large companies”, Management Research Review, Vol. 33 (4), pp380 – 392.

Zsidisin, G. A. and Hendrick, T. E. (1998), “Purchasing’s involvement in environmental issues: a multi-country perspective”, Industrial Management and Data Systems, Vol. 7, pp. 313-320.

Zsidisin, G. A. and Siferd, S. P. (2001), “Environmental purchasing: a framework for theory development”, European Journal of Purchasing and Supplying Management, Vol. 7, pp. 1-73.

Appendices

Appendix 1 Questionnaire (English)

Investigation of Green Supply Chain Management

Thanks for joining this research and the main purpose of this questionnaire is to investigate the pressure, practice, and performance of Green Supply Chain Management (green SCM) in Chinese construction industry. This is an anonymous questionnaire and the data will be kept safe. All of the collected data will only be used for academic research in this project.

Section A: Basic information

1. Type of company	□1 Stated-owned; □ 2 Sino-foreign Joint Ventures;

	□3 Foreign Direct Investment ; □4 Private Sector; □5 Joint Venture
2. How many employees does the company have?	Number of employees
3. Does the company have ISO 14000 Certification?	□1 Yes, □2 No
4. Does your company have the environmental management system?	□1 Yes, □ 2 No
5. What is the main business of your company?	

Section B: Drivers and Pressures of Green SCM

About the green SCM drivers and pressures of your company, to what extent you agree with following statements, (***1 Strongly Disagree, 2 Disagree, 3 Neither Agree Nor Disagree, 4 Agree, 5 Strongly Agree***)

	1	2	3	4	5
1.Either central or local environmental regulation is one of the drivers/pressure of green SCM in your company					
2. The product of your company may potentially conflict national laws					

3. The product of your company may potentially conflict foreign laws					
4. The Chinese regulations on environmental friendly products					
5. The foreign regulations on environmental friendly products					
6. The Chinese customers' environmental expectations on green products					
7. The foreign customers' environmental expectations on green products					
8. Your company plans to create a green image					
9. Your company has the environmental policies or mission					
10. Your company has liability for disposal of hazardous materials					

Section C: Practice of Green SCM

Please indicate to what extent the following green SCM practices are followed by your company, (***1 not consider, 2 plans to consider, 3 currently consider, 4 initiate implementing , 5 successful implementation***). And if your company has carried out some activities in the below, please indicate ***How Long*** it was done.

	1	2	3	4	5	Years

1.The senior management team supports environmental actions						
2. The mid-level managers is committed to environmental actions						
3. The departments co-operate to make environmental improvement						
4. Your company is compliant with environmental regulations and policies, and has a system in place to audit the compliance.						
5. Your company cooperates with suppliers to reduce pollution for environmental objectives						
6. Your company provides the environmental requirements to suppliers for purchased items						
7. Your company chooses suppliers with ISO 14000 Certification						
8. Your company cooperates with customers for more environmental friendly transportation						
9. Your company sells or recover from excess inventories or materials						

10. Your company reuses used materials or scrap						
11. Your company adopts cleaner technology processes for reduced resources (wastes, water, energy)						
12. Your company avoid or reduce use of hazardous of products or manufacturing process						
13. The Provincial and local or Central government coordinate the green SCM						
14. The Provincial and local or Central government build the infrastructure for facilitating environmental actions						
15. The Provincial and local or Central government provide environmental information and technical assistance to your company						
16. The Provincial and local or Central government popularize knowledge of environmental management in your company						

D Section: Performance of Green SCM

Relative to your company's objectives or competitors, how has your company during the past 3 years, performed with respect to both environmental and economic benefits. Because of implementing green SCM practices, there has been specific benefits achieved in each of the categories with following statements (***1 not at all, 2 a little bit, 3 to some degree, 4 relatively important, 5 important***)

	1	2	3	4	5
1.Reduction of solid/liquid waste					
2. Reduction of air emission					
3. Reduction of consumption of hazardous materials					
4. Reduction of consumption of energy					
5. Increase of profit margin					
6. Improvement of corporate image					
7. Increase of investment					
8. Increase of market share					
9. Increase of sales					
10. Increase of efficiency					
11. Improvement of productivity					
12. Improvement of product quality					

13. Reduction of cost for material procurement					
14. Reduction of fee of waste treatment or discharge					

Appendix 2 Questionnaire (Chinese)

关于绿色供应链管理的调查

谢谢您加入本问卷调查，这个研究的主要目的是调查在中国建筑行业中绿色供应链管理的动力，压力,实践,和履行表现。这是一个匿名的问卷调查，所有收集到的数据将会被安全保管，而且只会用于学术研究。

A 部分-基本信息

1.公司性质:	□1 国有企业； □2 合资企业； □3 外国直接投资企业（独资）；

	□4 私人企业； □5 股份制企业
2.公司员工人数大约是:	
3.公司是否通过 ISO 14000 环境管理体系认证？	□1 通过; □2 没有通过
4.公司是否建立自己的环境管理体系?	□1 已经建立; □2 没有建立
5.公司的主要业务或产品是:	

B 部分-绿色供应链管理的动力和压力

关于公司绿色供应链管理的动力和压力，在多大程度上您同意以下陈述, (1 完全不同意**, 2** 部分不同意**, 3** 既不同意也不反对**, 4** 部分同意**, 5** 完全同意**)。**

	1	**2**	**3**	**4**	**5**
1.国家或地方环境监管的法律，法规是公司绿色供应链管理的动力或是压力之一					
2.公司的产品与国内法律可能有潜在的冲突					
3.公司的产品与国外法律可能有潜在的冲突					
4.中国的法律，法规要求企业产品或生产过程达到一定的环保要求					
5.国外的法律，法规要求企业产品或生产过程达到一定的环保要求					
6.中国消费者的环保意识要求企业产品达到一定的环保要求					

7.国外客户的环保意识要求企业产品达到一定的环保要求					
8.公司计划塑造环保的企业形象					
9.公司有环保方面的企业规定或是目标					
10.公司有潜在的责任处理、处置有害物质					

C 部分-绿色供应链管理的实践

请注明公司多大程度上实践了绿色供应链管理 (1 完全不同意**, 2** 部分不同意**, 3** 既不同意也不反对**, 4** 部分同意**, 5** 完全同意**)， 如果公司或政府已经开展了下面的活动,请注明在你印象中已经实施了多长时间。**

	1	**2**	**3**	**4**	**5**	**年**
1.高级经理承诺一些环保行动						
2.中层管理者支持环保行动						
3.跨职能部门合作进行环保改进						
4.公司将环保标准纳入考量范围内						
5.公司与供应商合作以减少对环境的污染						
6.公司对采购物品提出环保要求						
7.公司选择通过 ISO 14000 环境管理体系认证的供应商						
8.公司与客户合作选择节能环保的运输方式						
9.公司出售或使用多余的材料						
10.公司出售使用过的材料或废料						

11.公司采用清洁技术流程减少能源，水的消耗，废物的产生						
12.公司避免或减少使用产生有害物的制造流程						
13.地方或中央政府协调绿色供应链管理						
14.地方或中央政府建立相应的基础设施支持环保						
15.地方或中央政府提供环保方面的信息和技术援助						
16.地方或中央政府普及环保方面的管理知识						

D 部分-绿色供应链管理的履行表现

联系公司的目标或是竞争对手,你如何评价贵公司在过去 3 年中因实施绿色供应链管理所取得的环境效益和经济效益（1 没有，**2** 有一些，**3** 比较多，**4** 多，**5** 非常多）。

	1	2	3	4	5
1.减少固体/液体废物排放					
2.减少废气排放					
3.减少有害物质的消耗					
4.减少能源消耗					
5.利润增加					
6.企业形象改善					
7.投资增加					

8.市场份额增加					
9.销售额提高					
10.效率提高					
11.生产率提高					
12.产品质量得到改善					
13.材料采购成本降低					
14.废物处理，处置费用减少					